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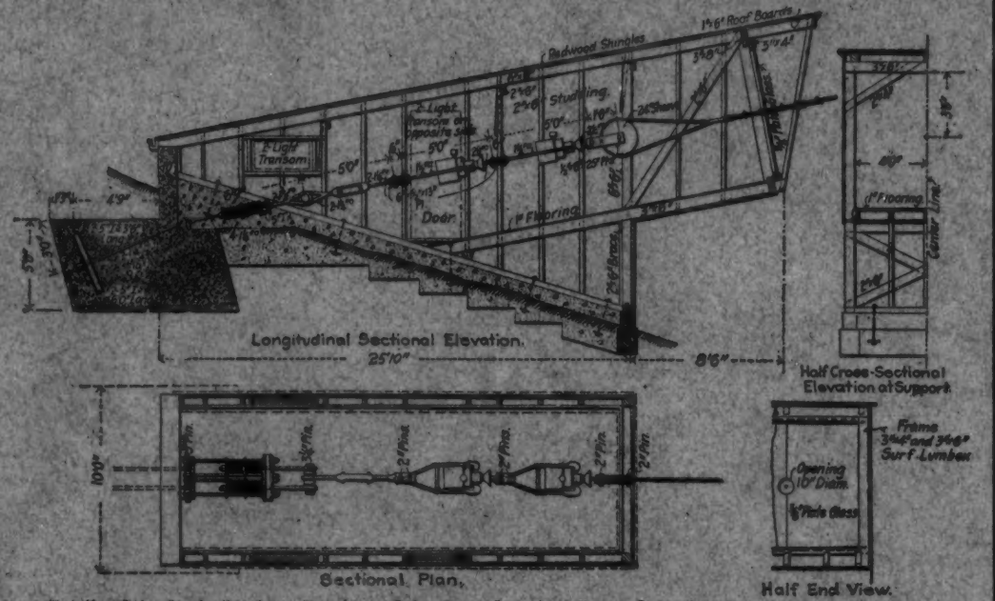

Details of the Strain Insulator Housings of the Great Carquinez Span of the Bay Counties Power Company.

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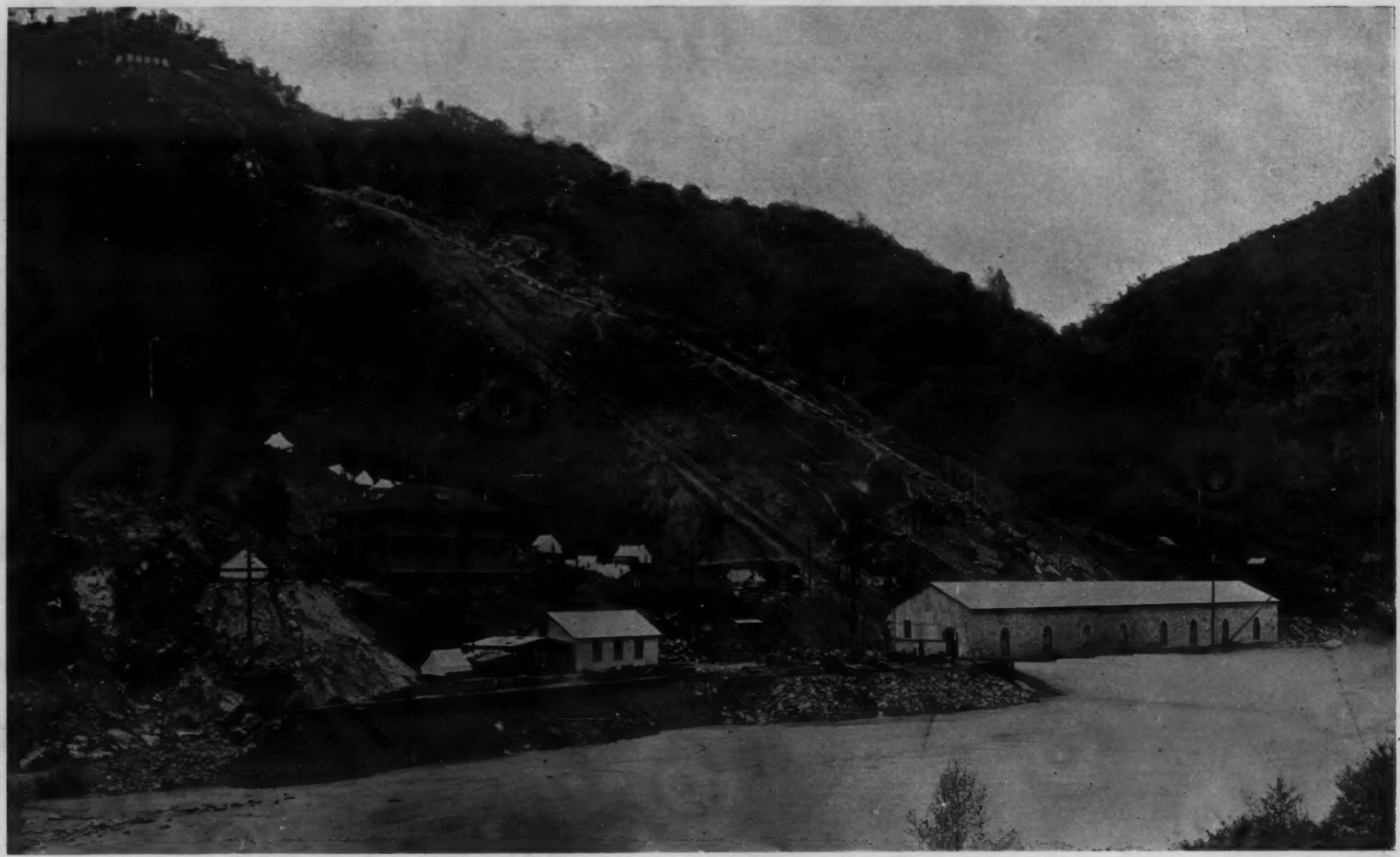

A GENERAL VIEW OF THE COLGATE POWER HOUSE OF THE BAY COUNTIES POWER COMPANY AND ITS SURROUNDINGS.

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THE JOURNAL OF
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Devoted to the Conversion, Transmission and Distribution of Energy.

VOLUME XI. SAN FRANCISCO, JULY, 1901. NUMBER 7.

The World's Longest Electric Power Transmission.

BY GEO. P. LOW.

IT WAS DETERMINED TO LOCATE THE POWERHOUSE AT THIS POINT.

A NARRATION, in popular form, of the events which have led up to the achievement in California of the greatest electrical engineering triumph ever accomplished needs a starting point, yet this is hard to locate, for there are, in truth, two beginnings; one, the technical beginning, which commences with the development of electrical engineering along transmission lines, and the other, the commercial beginning, which is the earlier one, starts back at the time when the mining, and then later, the manufacturing interests of the State first began to feel the pinch of its limited fuel supplies. Until of late power for industrial uses has been a commodity as expensive as it is indispensable. Except in mountainous localities, wood is not to be had for fuel, while the supply of California coal has thus far been really insignificant when compared with its total consumption, owing to its poor quality; the imported bituminous coals have generally sold at the all-but-prohibitive prices of from $6 to $9 per ton, and the discovery of oil will not possibly affect the status of the already perfected systems through which electricity is made the medium for bringing the limitless power of Sierran rivers to the very door of every consumer of power. So long as sun, sea and mountains exist, that long will water power prove unfailing as a source of energy.

Does the public realize what is meant when one speaks of the "limitless power of Sierran rivers?"

Is the scope of the term grasped, or is it within the capability of the human brain to comprehend it? Not long ago Mr. Alexander G. McAdie, local forecast official for the United States Weather Bureau, contributed an estimate of the energy represented in an afternoon fog bank so familiar to San Franciscans. From his statements, which are those of one in highest scientific authority, it may be shown that if the water held in suspension in a fog which passes over San Francisco for a few hours on summer days, could be condensed and applied to water wheels, sufficient power would be developed to turn every wheel of industry in this, the ninth largest city of the Union. This is the energy represented in just an ordinary afternoon San Francisco fog—a fog gathered from but, say, a hundred square miles of the great ocean frontage of the State of California. Each day the sun evaporates countless billions of tons of water from the ocean and carries it to high altitudes, whence, whether visible or invisible, it is borne to the utmost parts of this ever thirsty western country. The prevailing direction of the winds of the Pacific Coast are inland from the ocean, and in the Sierra Nevadas is found the great range of mountains that condense the moisture of the winds and returns the greater portion to the ocean through the streams running down their western slopes. So thoroughly do they do this that it seems, forsooth, as though the arid wastes of Nevada, Arizona and New Mexico confirmed the belief that the mountains wring the last bit of moisture from the wind. No man will ever know in terms of horse-power the amount of energy that is thus bestowed upon California by the beneficent Sierras.

Brief comparisons may, however, convey some estimate of the capabilities of but two of nature's most familiar forces—the waterfall and the wind. It is estimated that the average annual rainfall covers the earth's surface to a depth of about 5 feet, or an amount of water which, if flowing at the depth of Niagara's crest, would make a stupendous cataract 4000 miles wide and of a height considerably over a mile. This represents an amount of energy in comparison with which the entire aggregate of power used in the world's industry is but an iota. As for the energy of the wind, to harness which in a serious industrial manner has thus far utterly baffled man's ingenuity, Prof. R. H. Thurston has shown that if an average velocity of $16\frac{7}{16}$ miles per hour be assumed, the wind power of every square mile of the earth's surface would yield about 80,000,000 horsepower, which is not far from the aggregate of the existing steam power of the world.

THE NEVADA COUNTY POWER HOUSE—INTERESTING AS BEING THE FORERUNNER OF THE BAY COUNTIES SYSTEM.

Of such is the natural source of power which is being utilized in small part by the electrical transmission interests of the west. Their work, too, is heroic, as man's work goes, for, with the impounding and conserving of torrential streams, and the diversion, fluming, ditching, tunnelling and piping of their waters, it can by no means be said that water power is a ready-made source of mechanical energy.

Speaking generally, man has long had a passive realization of the tremendous power stored up in mountain streams In California, where the great waterpowers lie on the edge of the largest and most fertile valleys in the world—valleys having an almost unlimited demand for power and light, this realization has become an active one, and as the principles of the science of electricity became understood, and as skill was acquired in the conversion of mechanical energy into electrical energy, thence back into mechanical energy again, then electrical engineers

realized that they had at their command a tractable medium for taking water power from its mountain home and delivering it to a valley market. This delivery of power to regions widely separated from its source constitutes the business of electric transmission, and the installation about to be described presents an example of financial and engineering boldness that in many regards is without precedent. It takes a thorough knowledge of local conditions accompanied by a strong courage of conviction to embark capital in an enterprise so much at variance with the lines of any previous industry as were those of the proposed electric power transmission schemes of a decade or less ago. Then it was mainly a question of transmitting power for lighting purposes alone, because electric motors that would operate on the kind of electric current that must be used in transmission work had not been invented.

COLGATE POWER HOUSE NO. 1, BUILT BY THE YUBA ELECTRIC POWER COMPANY.

Aside from experimental work, practically the only plant in the world that had up to that time attained acknowledged success in this direction was the little 300 horsepower plant that took water power from the great Tivoli aqueduct and delivered it in the City of Rome (Italy), seventeen miles distant.

The nucleus of the great transmission plant of the Bay Counties Power Company of San Francisco is found in the power transmission that for the last five years has delivered electric light and power in Nevada county, California, and the mining interests thereabouts. The credit for the conception of this plant belongs to Mr. Alphonso A. Tregidgo, who, in the winter of 1891 and '92, located a water right on the South Yuba river for the purpose of developing electric power to be transmitted to Nevada City, four miles distant. The precedent on which the undertaking was based was the Tivoli-Rome transmission, built in 1886, but he was altogether unsuccessful in interesting sufficient capital until the spring of 1895, when, through the efforts of Mr. Eugene J. de Sabla, Jr., of San Francisco, and his associates, work was begun in building the plant in July, 1895, and so diligently was it prosecuted that in February, 1896, the system was finished through to Nevada City, Grass Valley and the adjacent mines, to which it was able to deliver light and power to the extent of about 1000 horsepower.*

During the spring of 1897 the original plant was doubled in capacity and Nevada county industries had electric power at their command to the amount of 2000 horsepower.

In the meantime, in 1897, certain water rights had been acquired on the North Yuba river and the Yuba Power Company was incorporated in September of that year by R. R. Colgate of New York, Eugene J. de Sabla, Jr., and John Martin of San Francisco, the latter of whom has since formed the Central California Gas and Electric Light Company, which is to be a large consumer of the current of the Bay Counties Company. This Yuba company determined to build a 1500 horsepower

*For description of the Nevada County Transmission, see THE JOURNAL for November, 1895, Vol. I, page 107 *et seq.*

plant on the line of an existing irrigation canal at a point where the water was dropped 300 feet, some eight miles from Smartsville, in Yuba county, and so diligently was the work prosecuted that the entire plant was finished and delivering electric power into the Brown's Valley mines and the city of Marysville, twenty-two miles distant, in April, 1898.* This was a record-breaking installation, as the entire work was finished and the plant was in operation within the remarkably brief time of four months and five days after its building had been determined upon.

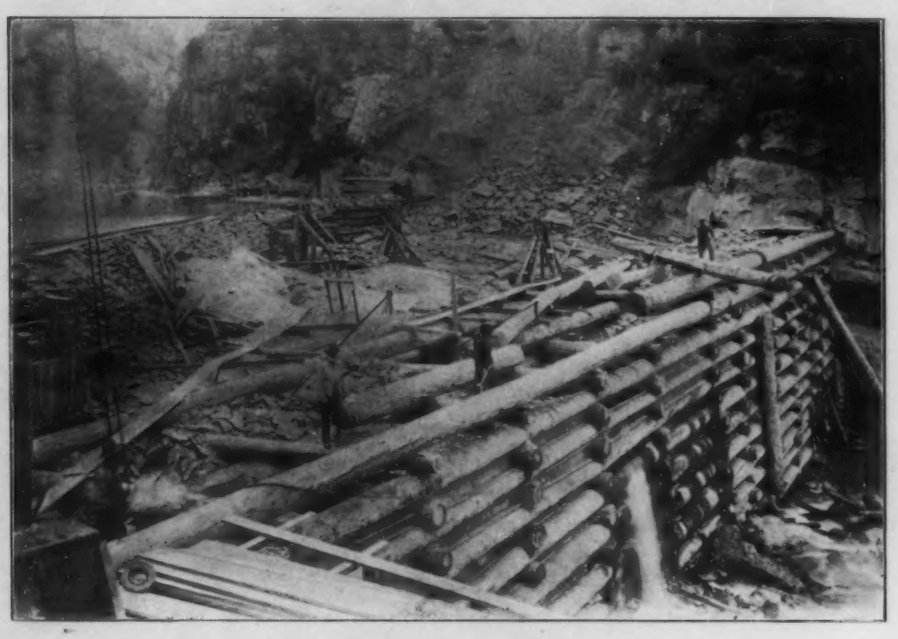
power house, known as Colgate Power House No. 1, was built on the north bank of the canyon of the North Yuba river at a point where the old Missouri Bar trail, so well known in early mining history of the state, crosses the river. A new, much larger, and most substantial flume was built, the height of the dam was raised by some 10 feet, water wheels and electrical machinery to the amount of 5000 horsepower were installed and additional transmission lines were built therefrom to Sacramento, sixty-one miles distant, and to the gold dredging districts near

THE NEW DAM AND HEADGATES OF THE FLUME.

As had been the case in Nevada county, the capacity of the Yuba plant for delivering power was very soon absorbed and hardly a year had elapsed before the company was compelled to resort to methods of great engineering interest to supply temporarily the heavy demands for power that were thrown upon the generating station. This situation necessitated the permanent enlargement of the Yuba system, to accomplish which the Yuba Electric Power Company was organized, with a capitalization of $1,000,000, for the purpose of absorbing the properties and business of the Yuba Power Company and for developing its water power to the utmost extent. A new Oroville, some thirty miles distant, but before the work in hand was completed—in fact, long before the new power house was in running order—further great demands for power had arisen, which resulted in the consolidation of the Nevada County Electric Power Company with the Yuba Electric Power Company, and the organization of the Bay Counties Power Company, into which the two companies named were merged.

The Bay Counties Power Company, which has a capital stock of $5,000,000, of which $3,000,000 in stock is issued, was incorporated in June, 1900, and has the following officers and directors: Mr. E. J. de Sabla, Jr., president and general manager; Mr. Wm. M. Pierson, vice-president and

*Described in THE JOURNAL for May, 1898, Vol. V, page 145.



THE DAM IS OF ROCK-FILLED CRIB CONSTRUCTION.

attorney; Mr. C. A. Grow, secretary and treasurer, and Messrs. J. C. Coleman, Richard N. Hotaling and George A. Batchelder, all of San Francisco and R. R. Colgate, of New York, directors. Mr. Batchelder represents the Eastern banking houses that advanced the company two and a quarter million dollars for the completion of the consolidated projects, taking its thirty-year 5 per cent. bonds It is significant of the commercial success of the enterprise that not only its two predecessors, the Nevada County Power Company and the Yuba Power Company, but even the Bay Counties Power Company itself, with its great expenditures during construction, have each and every one of them earned materially more than their bond interest from the moment when their water wheels began to turn in regular service. At present, the lines of the Bay Counties Power Company, if placed end on end, would reach from San Francisco to New York; they supply power for the operation of most diversified mining, manufacturing and transportation industries, extending from the operation of Cornish pumps and mining hoists of the deep gold mines of the Mother Lode to the driving of the street cars in San Jose, in Santa Clara county—over 200 miles apart. Between these points nearly every imaginable industry will contribute its quota to the treasury of the company—the gold dredges of the Feather river, the electric lighting of more than twenty cities and towns, the pumping of water for municipal use (pumping it in for irrigation districts and pumping it out for reclamation districts), the flour and woolen mills of Marysville, the railroad shops of Sacramento, the flour mills of Vallejo and Port Costa, the Navy Yard at Mare Island, the powder works at Pinole, the Smelting and manufacturing companies along San Pablo Bay, the state institutions at San Quentin and Napa, the street railways of Oakland and the presses of its daily papers.

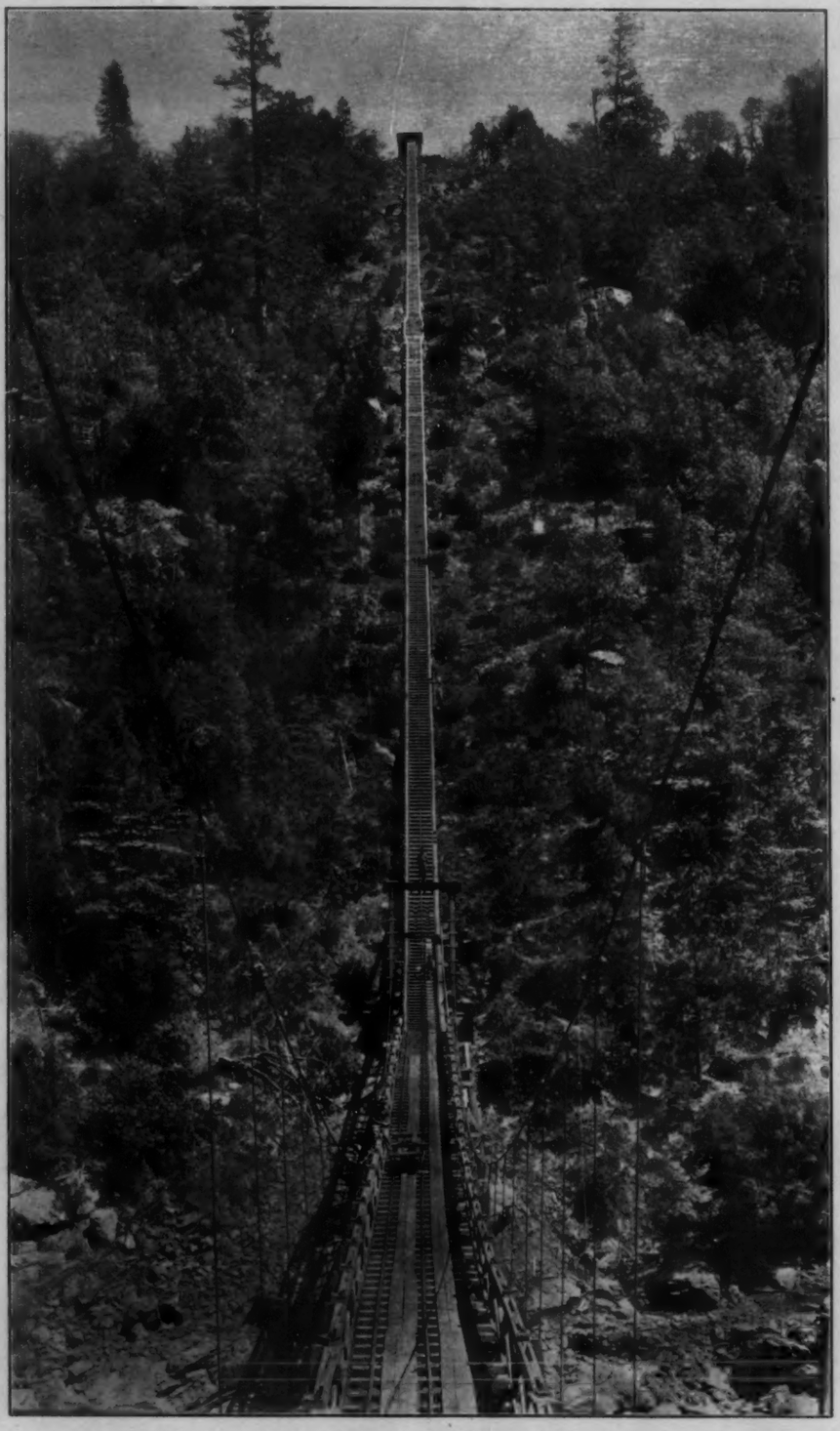
It is operating in, or has connections enabling it to operate in, sixteen of the most populous counties in central California, which contain one-half of the population and three-fifths of the assessed valuation of the fifty-seven counties of the state. The energy of its water wheels is delivered a distance practically double that heretofore effected. Its initial electric pressure for distribution over its enormous expanse of territory is 40,000 volts, which equals that used in the Provo-Mercur transmission in Utah—so long distinguished as the highest electrical pressure in commercial use. This voltage, however, is but the *initial* pressure used by the Bay Counties Power Company, for the voltage is to be increased, first to 50,000 volts, then to 60,000 volts, and then possibly to 70,000 volts or even higher in order to minimize the losses incurred in transmitting such great amounts of power over long distances involved in transmission over a radius of 200 miles. It has built a structure across

BETWEEN THE DAM AND CHUTE CAMP CABIN.

the Straits of Carquinez* of more than three times the length of the great Brooklyn bridge and which is, therefore, the longest single span between two supports which the world has ever seen. Over this structure the Bay Counties Power Company transmits power with which to fulfill its contracts in Contra Costa, Alameda and Santa Clara counties. The company is at present either actually delivering, or is contracted to deliver, or is negotiating to deliver, with every indication of shortly delivering, mechanical energy to the amount of 17,000 horsepower. It is operating three separate and distinct generating stations which, together, have an aggregate capacity of some 23,000 horsepower, besides possessing water rights enabling it to deliver a minimum of 20,000 horsepower additional. Some of its dynamos are the largest in use in any water power plant in the world outside of those at Niagara Falls, and indeed the system of the Bay Counties Power Company is second to Niagara in point of horsepower capacity.

A trip over the system of the Bay Counties Power Company at this time of year can scarcely be done in less than two weeks' time. At Marysville one first sees the Yuba river, which fifty years ago found no barrier in flowing along its natural course, but hydraulic mining long since shoaled the stream until now hundreds of thousands of acres of the fine farming lands of the surrounding counties would be inundated each year were it not for the great levees that have been thrown up to confine the river. Indeed where the Yuba was a few rods wide in the fifties, it has a width in some places at highwater of two or three miles on the low lands, where it pursues its way over a shallow course to its junction with the Feather river. After seeing the immeasurable quantity of soil and slickens that are deposited along the rivers of some of the valleys of California, one does not further wonder what has become of the earth which constituted the mountains that the early miners washed down and apparently removed from off the face of nature.

It is along one of the levees of the Yuba river that the road from Marysville to the Yuba power house of the Bay Counties Power Company follows for the first five miles of its route; then another five miles through an open country brings one to the foothills, where the real beauty of the drive begins, and this beauty grows upon one with ever heightening interest as the elevation increases. California is in all of its springtime glory as this is being written. The mountain sward is as green and trim as any lawn; the oaks cast inviting shades, the luxuriant wild flowers, the profusion of



THIS TRAMWAY AND BRIDGE WAS BUILT AS THE ONLY MEANS BY WHICH THE FLUME TIMBERS COULD BE LOWERED DOWN THE BLUFF AND ACROSS THE RIVER.

Vide "The Great Carquinez Transmission Span" in THE JOURNAL, Vol. XI. page 91 *et seq.*

orange and lemon trees, the balmy air and the song of the meadow lark make the country so delightful that the twenty-two mile drive to the Yuba power house passes, alas, too quickly.

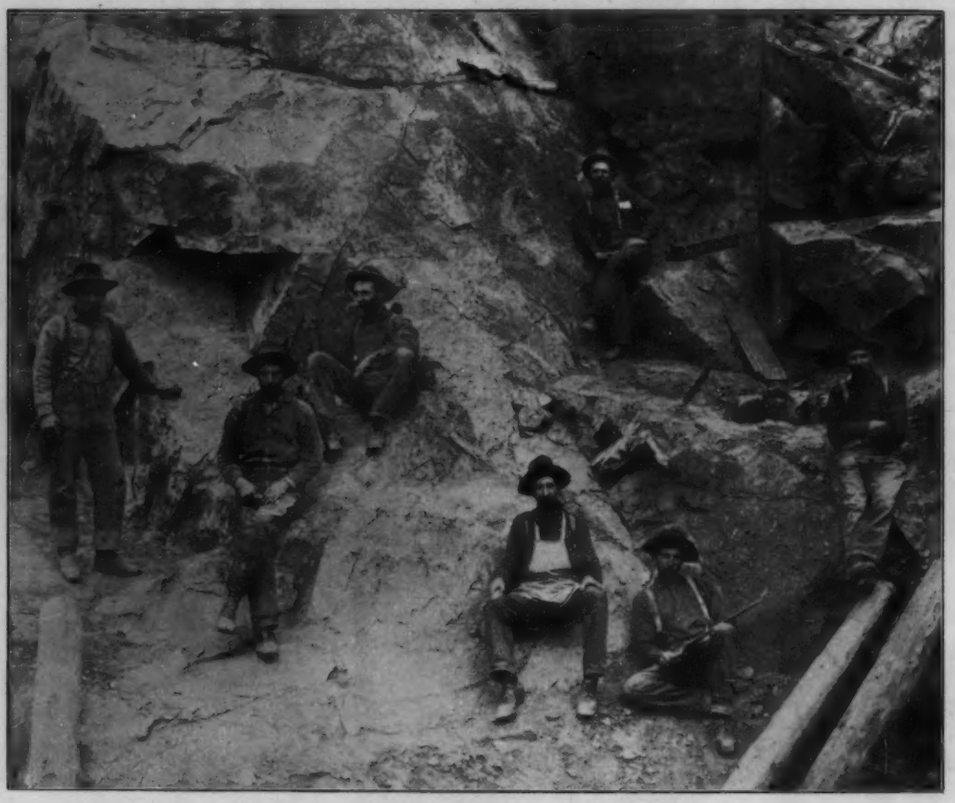
LOOKING UP THE FLUME FROM CHUTE CAMP CABIN.

This Yuba power house, now irreverently referred to as the "old plant," contains three 500 horsepower dynamos that are driven by the water power due to a drop of a little more than 300 feet in the level existing between the upper and lower courses of the canal. Originally the entire output of the Yuba plant was consumed in operating the mines and stamp mills of the Brown's Valley mines and in regular electric lighting and power service in and about Marysville and Yuba City. At the time of its installation its noteworthy characteristics were found in the facts that the pressure it used in transmission work, namely 16,000 volts, was considered to be high although it is now looked upon as being a very moderate potential, and also that from the outset the plant has been carrying all the power it could deliver. At present the Yuba plant is running at full load; for inasmuch as all of the water which runs in the upper ditch must be promptly delivered to the lower ditch without diminution of the supply used in farming and mining, further down the ditch it is not possible to restrict the amount of water delivered to the water wheels, hence they are always delivering their maximum horsepower to the dynamos which, in turn, deliver almost an equivalent amount of electrical horsepower to the main system of the Bay Counties Power Company. It should be understood in this connnection that although the three power houses of the company are located many miles from each other, they are "tied" together by pole lines which enable them to be operated in unison as a single station as easily as though they were combined under a single roof.

THIS IS THE FLUME TENDERS' CABIN AT THE FOOT OF CHUTE CAMP TRAIL.

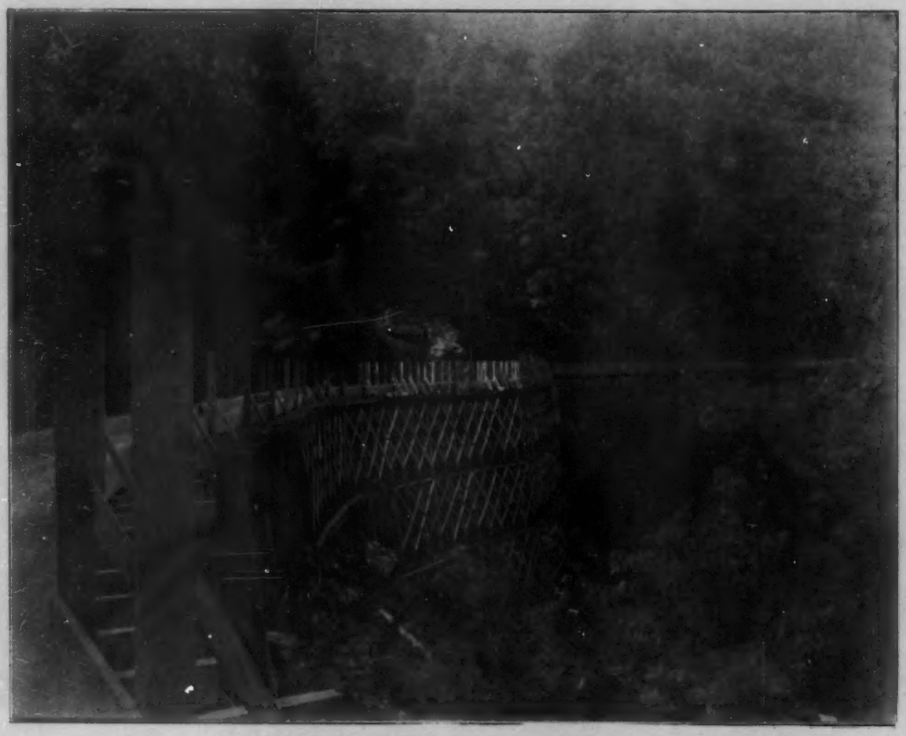
Though it is but eight miles or so from the old Yuba plant to the Colgate power house by way of the pole line which connects them, it is far quicker and easier to go from one to the other by way of the round-about road, thirty-one miles long, than to take the "short cut" across the mountains. I fear, however, that he who takes the longer trip will doubt my veracity, for what with the roughest road that ever "happened," what with going over it so like the wind that the wheels strike only the "high places," what with reflecting upon the unceremonious way in which the conveyance throws you up in the air, drops you, then meets you half way back with unrelenting jounces.

what with dust that chokes and grades that affright, and what with aching muscles and tired bones, one fails to see wherein any other route could have been more difficult, or wherein this one could possibly be considered an easier one. The road forks at Dobbins' Ranch, a lively little settlement way up on the pines of Yuba county, where the traveller gets his last glimpse of civilization before reaching the veritable jumping-off place found in the Yuba canyon. From Dobbins it is three miles in a southerly direction by road to Colgate, where the great power house is located, and from Dobbins, too, it is five miles or so up and across other mountains to the top of the "Chute Camp Gulch," down which one must almost "take a header" before he can walk along the flume to the diverting dam, a mile and a half above.



PRETTY TOUGH COUNTRY IS ALONG THE LINE OF THE FLUME.

I can never forget the experience I had in going over this self-same country three years ago when the Yuba plant was built, nor can I say that any particular pleasure was experienced at that time in traversing that wretched trail. When the original owners of the water right built the first flume, a contractor erected a little sawmill at the head of the gulch on the top of the mountain, the lumber for building the flume was sent through a V-shaped chute to the carpenters' camp near the river—hence the name, "Chute Camp Trail." The trail is better now than it was three years ago—then it almost stood on end. It was said that its length is about three-quarters of a mile, but in my recollection it was very much of a mile indeed. My companion on that trip was the superintendent of the district flume and ditch, a mountaineer named Armstrong (Charles L. Armstrong), who had justly earned the reputation of out-walking the pendulum of the best eight-day clock on earth. I had never walked for a living, as Armstrong had done from time immemorial, and it had been my fortune, for good or for ill, to go with him the afternoon before on a "little" jaunt from the Yuba power house to Indian creek flume and return. I understood that it was to have been a five-mile walk, and so I struck out



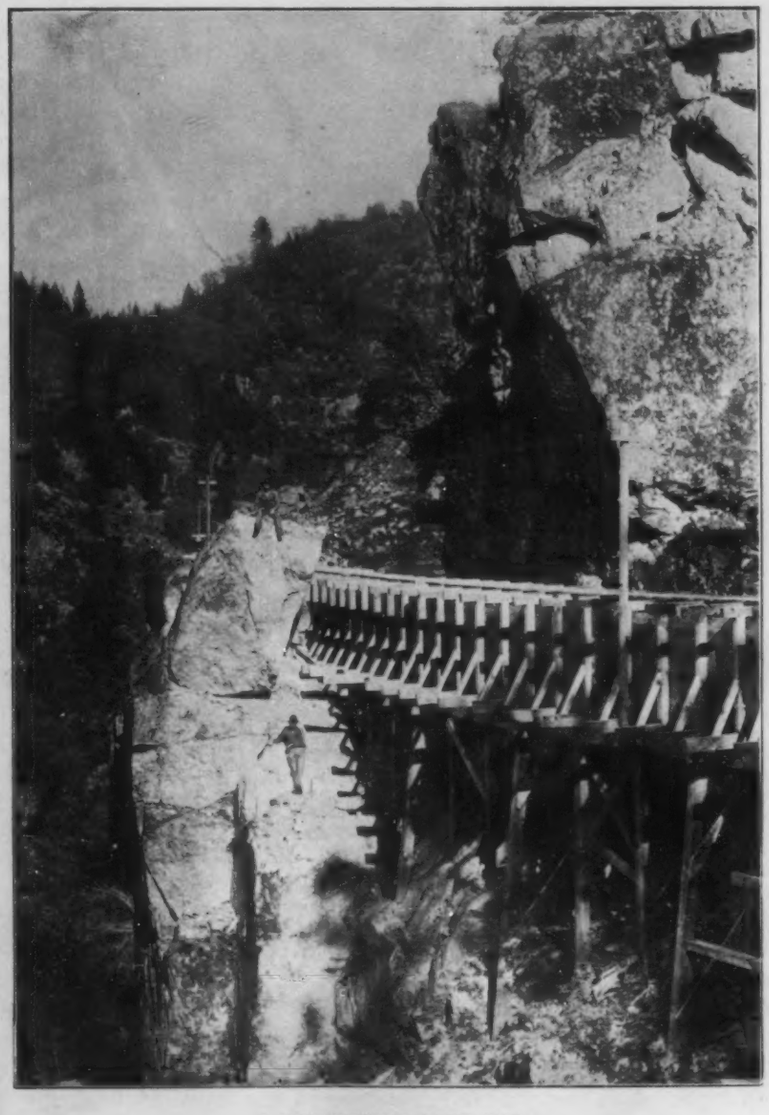
SOME PORTIONS OF THE WATERWAY ARE IN GRATEFUL SHADES.

with agility, but I had reckoned unwarily. Mountaineers walk up hill and down dale with the measured, incessant, unrelenting step of a perpetual metronome. They never stop, they never tire, nor lose their breath, nor get athirst, nor take "spells," nor look at landscapes, however enchanting. They go ahead mechanically in the accomplishment of their fiendish ambition to push the earth behind them with their legs until the desired point upon it has at last been brought to them. Armstrong was of this ilk. We went up, and across, and down six big mountains in his merciless pendulumistic way before we reached Indian creek, where I hustled around and took some photographs while he sat down on the flume—except at the moment of picture taking, when he stood up. Then we started back to the power house, but not until I had held him long enough to remark, between pants, that we had gone a long way, it seemed to me, for one-half of a five-mile walk.

"Five miles each way," quoth he, speeding onward.

But when, seemingly, centuries later that afternoon, we neared the power house, my aching, quaking knees gave out and in coming down from the head of the pipe line I realized for the first time what a wise provision of nature steep mountain sides are, for they enable the footsore and weary to ape Kelly, of vernacular fame, and "slide" in descending. So it was that at last I was enabled to reach the power house albeit in a state of collapse. That evening explanations followed and to my relief I found that the "five miles each way" of my friend Legstrong was an air-line distance, and that, soft of muscle as I was, I had walked with military precision some twenty odd miles that afternoon over the roughest, rockiest, ruggedest trail that man had ever hacked out of mountain sides.

THE PIONEERS "NET" OF DOBBIN'S RANCH

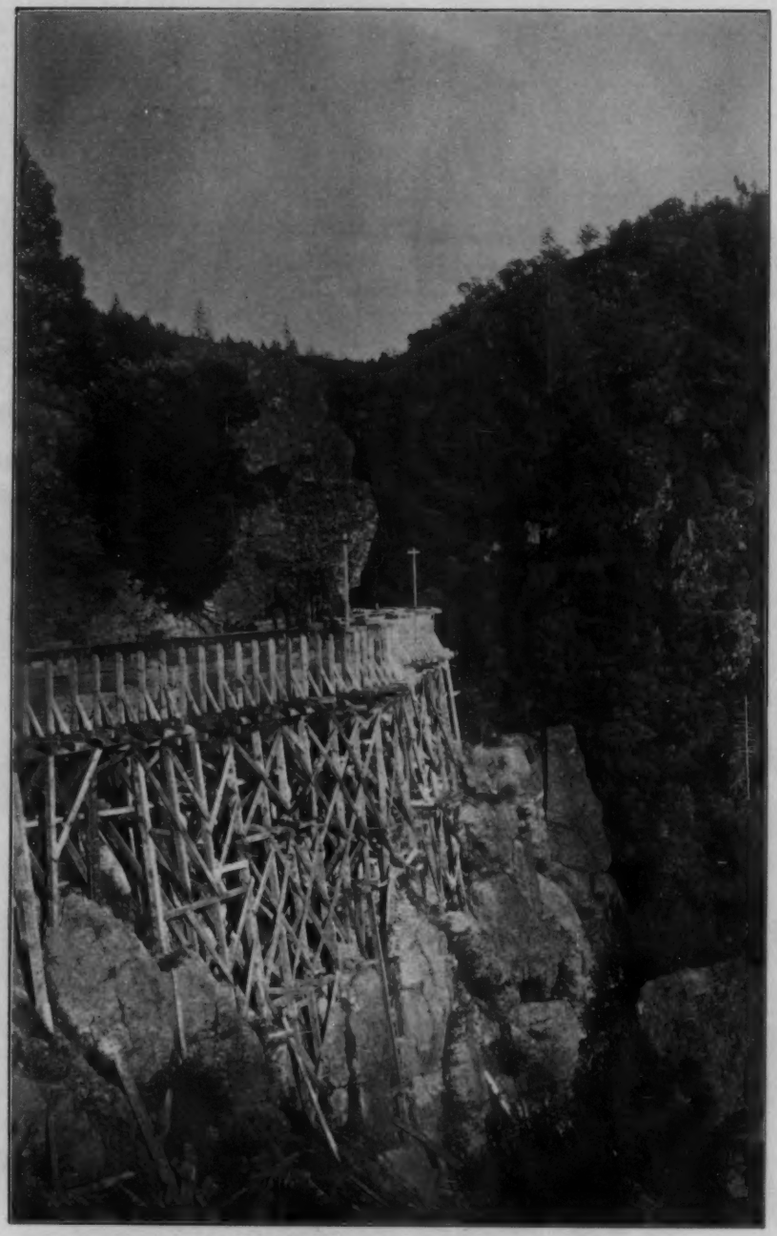


A PICTURESQUE ROCK CUT.

And so, the next day, with re-echoing aches, which large and oft-repeated applications of pain-killer had allayed not, I found that my joints were of the "wabbling universal" variety as I descended the Chutes Camp trail. In fact, I confess that I contemplated the prospective absence of an ambulance at the end of the day's ten-mile trip ("ten miles," quoth Armstrong that time) with feelings akin to despair. My alpenstock did little good in the descent; I clung on desperately to young pines, and maple, and dogwood as I vainly tried to lower myself down easily, and finally had about concluded to accept my gentle (?) guide's advice to "grease the ways and slide," when we reached the flume, hidden amid the trees and brush. Then was experienced, though with some misgiving as to the outcome, the dubious satisfaction of knowing that most of the rest of the walk would be on a level flume which would bear some semblance to the sidewalks of a civilized community. But once more I had reckoned unawares, for before the day was gone I had learned a true characteristic of flumes built in mountain fastnesses. The boards constituting the footwalk on the upper end of the flume near the sawmill were wide and very firm, but the further down one went the narrower they became, until 18-inch boards dropped to a width of 12 inches, then to 10 inches and on down to 8, 6, and even 5 inches, until one was forced to the belief that if the flume were much

longer the footboards along its lower end would be but bed slats, or maybe like whalebones, even necessitating, perchance, that to go over the flume one must be possessed of the equilibristic qualifications of a tightrope walker.

Such was the old flume, but the newly constructed Bay Counties' flume possesses none of the uncharitable attributes of its predecessor. The new structure is more than four times the size of the one which it replaced, and it is built with the solidity of a railroad trestle. No trace of the old flume remains, for in building, the new one was placed on the line of the old flume, with the bottom of the new structure just a foot or so above the top of the old one, which, by the way, was in use for ten years before it was supplanted, and which, furthermore, carries with it the reasonable assurance that the route of the flume has been well "seasoned," so far as liability of breakages from falling rock is concerned. A so-called "crib" dam, built up of great logs and broken rock, diverts the water of the North Yuba river into the flume through massive concrete headworks. Since the erection of the dam the silt and gravel brought down by the river has filled in behind the dam and raised the bed of the river level with the top of the dam, thus removing the danger to which the dam is exposed when the river becomes torrential. This dam is 167 feet in width with a height of 40 feet, and during the winter just closed the water flowed over its crest in a depth of 14½ feet. Normally, however, its depth is but 2 or 3 feet, in comparison with which the amount of water diverted into the flume seems very small. To build this flume was no mean task. Lumber could not be had from the immediate vicinity, so it was furnished from a sawmill built in the heart of a forest in Nevada county some ten miles distant from the dam. A gravity tramway, 1275 feet in length and having a gradient much steeper than any hill in San Francisco, together with a suspension bridge spanning the Yuba river, were also erected, and in all a full 8,000,000 feet of lumber was thus delivered to and utilized in building the flume. To get this lumber of the proper quality 11,000,000 feet were cut, but some 3,000,000 feet was culled out on account of having sap, although this has since been sold in the open market. In fact, great experience is required to know just what variety of lumber is most suitable for flume construction; for instance, in the Bay Counties flume, all underpinning and all superstructure is of all-heart red spruce, all sills are of heart cedar — that is, just the hearts of cedar trees; all posts and caps are of heart yellow pine, all boards are of heart yellow or heart sugar pine, and all battens are of sugar pine. The flume was built upon the plans of Mr. W. R. Eckart, whose engineering eminence is known the world over.

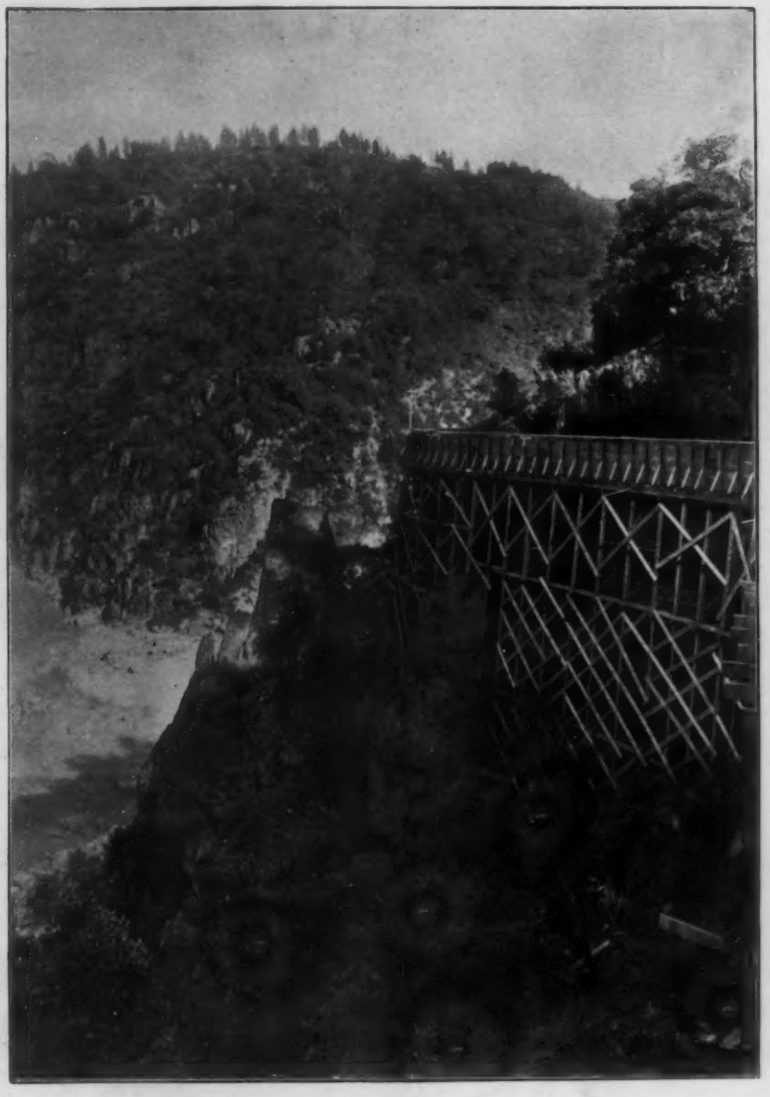


THE "CAPE HORN" OF THE BAY COUNTIES FLUME.

Seven and six-tenths miles below the dam, the flume delivers its water into the pipe line, and the grade of the flume is such that, if worked to full capacity, it would carry the enormous volume of over 23,000 cubic feet of water per minute—a quantity which it may always be assured of having in view of the fact that its watershed is 532 square miles in area. From the flume, the water is taken to the power house through five separate steel and iron pipes, each 30 inches in diameter, whence it is delivered to water wheels that in turn drive the great dynamos with which the station is equipped. These dynamos are capable of delivering above 14,000 horsepower to the transmission lines, and three of them have a capacity of 3000 horsepower each,

making them the largest horizontal shaft dynamos driven by water power in the world. Similarly, the buckets used on the water wheels are the largest and heaviest ever made for a wheel of the tangential jet type. They are of cast steel and at times the force of the blow thrust upon them by the jet of water reaches over thirty tons.

It is difficult, if not impossible, for the layman to appreciate the force represented in a stream of water as utilized upon the water wheels of electric transmission plants in California. The first station to use waterpower coming from an extremely high altitude, or "head," as it is technically termed, is the plant of the San Joaquin Electric Company, delivering power into Fresno and Hanford, Cal., over lines measuring 25 and 62 miles in length respectively. This plant uses water under a head of 1411 feet, which exerts a pressure of 609 pounds per square inch on the pipes at the power house in consideration of which this first use of water at extreme high pressure in electric transmission work was an experience of most queer hydraulic antics. The "tail race," along which the water flows away from the station after it has been used by the water wheels, was, for instance, constructed in a usual manner, under the supposition that the water would run out of it in an ordinary peaceable fashion. On turning on the water, however, it refused to go out along the bottom of the tail race, but instead it rolled up the sides of the pit to the under sides of the planks covering it, along which it rushed madly out almost horizontally for a distance of 60 feet, where it struck a granite boulder and was lost in spray. The streams applied to water wheels in this class of water power plants are like those from a fire engine, only of far more terrific fury. After the Fresno plant had been running two days, the stream of water had cut through the concrete wall of the wheel pit and into the seams of the bedrock, coming out within the power house. To obviate this, a 14-inch steel pipe, 4 feet in length and having a heavy steel plate across the lower end, was let into the bottom of the wheel pit in line with the jet, the idea being that the pipe would fill with water and form a water cushion to take up the blow. Instead of doing this, however, it merely reversed the direction of the stream, and the waste water landed on top of the power house, not taking the usual course. Then some one recommended that the wheel pit be dammed up so as to carry 2 or 3 feet of water, which would tend to prevent the emptying of the cushion pipe, with the only difference from the preceding experiment being that in addition to the waste water the water impounded in the wheel pit was also landed on the station roof and thereabout. Nevertheless the "water cushion" pipe was allowed to remain, but it was filled level-full with concrete and the bottom was completely floored over with 3-inch planking, which was sheathed for 3 feet about the nozzle with ⅜-inch steel plates. At that time the water was slightly muddy and considerable granite sand had been washed into the tail race, and as a result in less than three days a ¼-inch jet, which had been left in, had worn its way through the steel plate and the 3-inch planking, and was at work upon the demolition of its old enemy — concrete and masonry. The heroic method of feeding a fresh cast-iron plate 1½ inches in thickness to it as often as necessary has now been resorted to as the best solution of the problem.

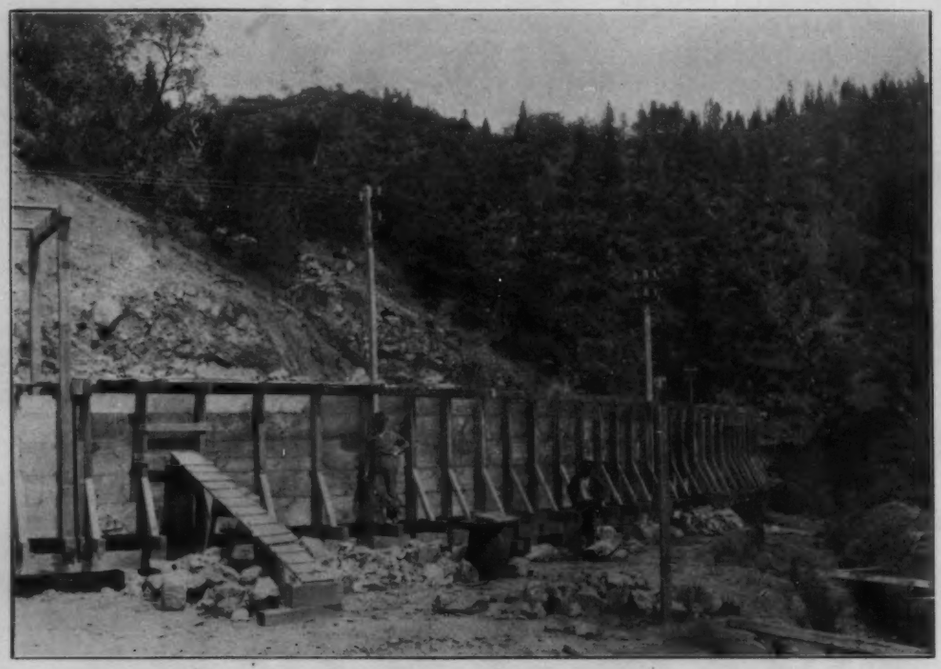


AT THIS POINT THE NORTH AND MIDDLE YUBA RIVERS JOIN.

Again, it seems incredible that conditions could ever exist that would render hard, unrelenting, unyielding steel almost as elastic as a garden hose, yet the starting-up or shutting-down of water wheels in the Fresno plant causes a water shock which is so perceptible that if one sits astride the pipe he can feel it expand and contract, like the breathing of a giant reptile. In the Mount

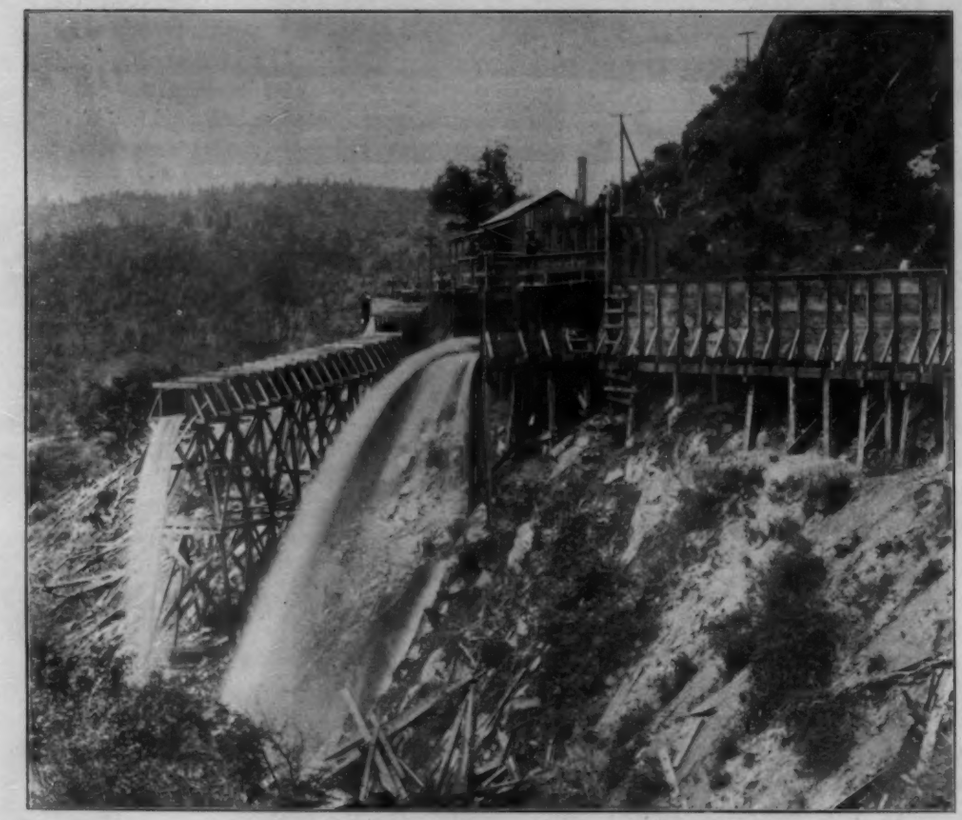
Whitney transmission, the water leaves the nozzle at a velocity of 17,800 feet per minute, which is at a speed of over three miles a minute; while in the Comstock mines, a tiny leak of water, under a head of 2000 feet, and making a stream no larger than a cambric needle, bored its way through a 2-inch plank like a rifle shot.

The Bay Counties' pipe line at the Colgate power house delivers no such pressures as these to the water wheels, for its head is but 702 feet; nevertheless the pressure resulting therefrom is about 300 pounds per square inch, which is by all odds quite enough to be treated with every deference. At times when the dynamos are not being worked to full capacity, portions of the stream shoot out into the river without striking the buckets of the water wheels, and if one drops a stick of wood or a board into the stream it will be shattered into splinters, while to drop a rock as big as a man can lift into it, causes evident resentment on the part of the stream, which retorts with a "biff" and a "bang" that send the rock across the canyon like a shell from a cannon.



JUST BEFORE REACHING THE PENSTOCK THE FLUME FINDS A LITTLE LEVEL GROUND.

The Colgate power house consists of two sections, the first of which was built by the Yuba Electric Power Company, and known as "Colgate No. 1," while the second section, of equal capacity, was added by the Bay Counties Power Company, thus doubling the size of the original station. The building is of stone, the interior is of concrete, iron and steel, and the entire structure is absolutely fireproof. It measures 275 feet by 40 feet in size and a distinguishing characteristic is the great concrete subway extending along the entire length of the building and through which all wires and cables connecting the dynamos to the transformers are run.

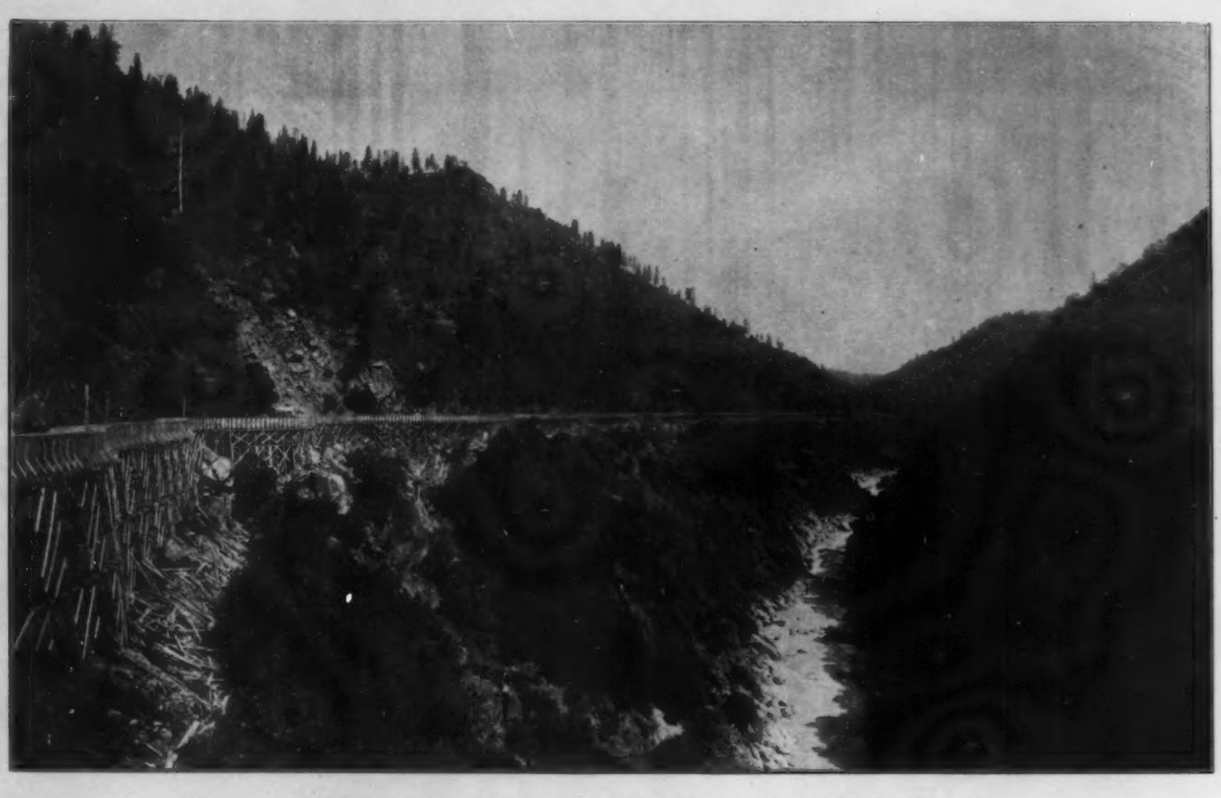


A SPILLWAY, SHOWING THE SINCE-REMOVED TIMBERS OF THE OLD FLUME.

It seems inevitable that at this point some brief and very elementary reference should be made to the means that have been adopted by the electrical transmission interests to bring the bulk of the energy of the distant water power in to the centers of commerce and industry across miles and miles of country. In every public place the engineer has, at one time or another, been plied with the query: "Isn't the

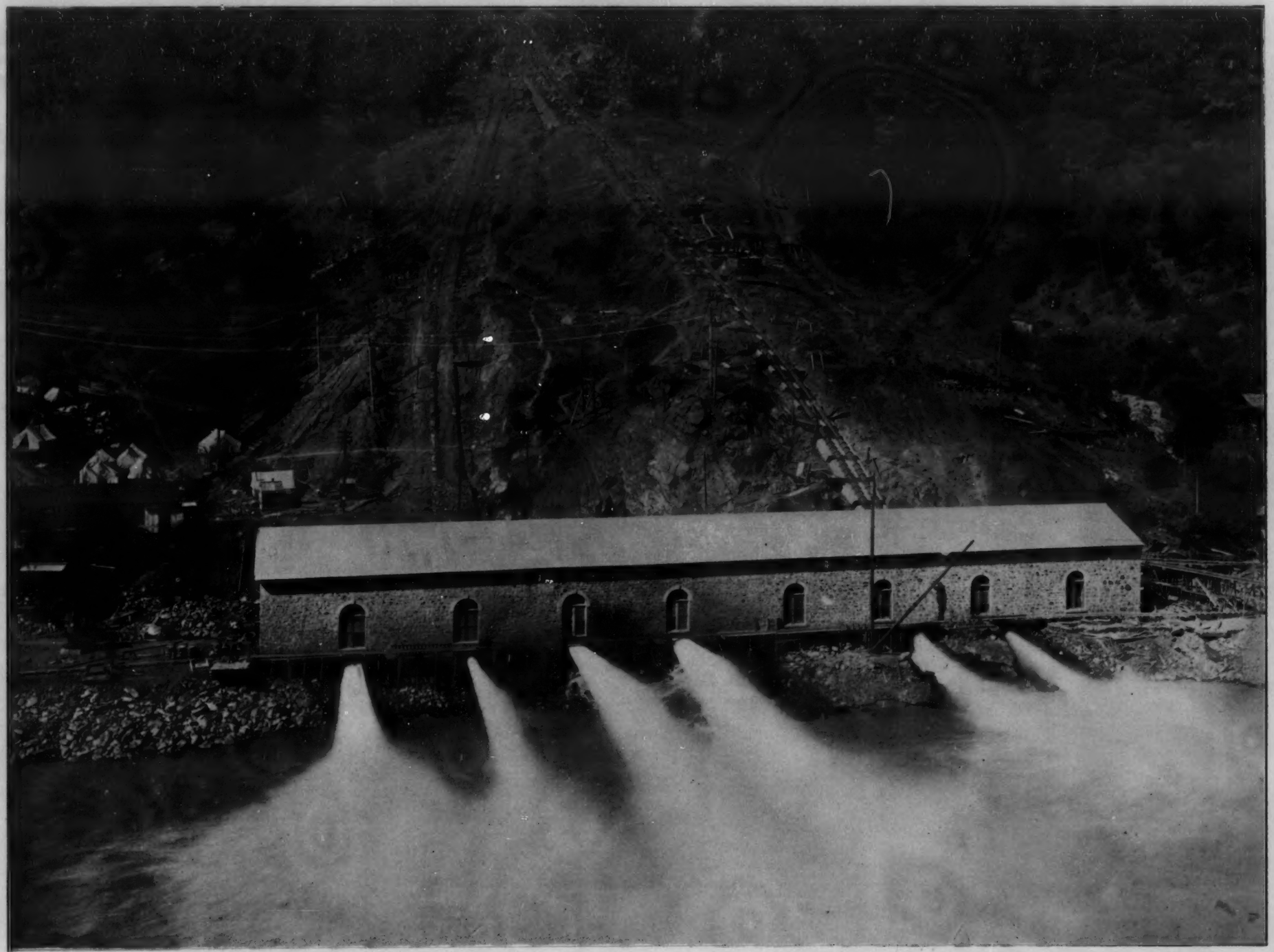
loss of electricity very great in sending it over such long distances?" In answer the engineer can only make reply that such is emphatically not the case, for the science of electricity has long since passed the stage which enables its savants to control pressures that go a long way toward accomplishing the annihilation of distance. The fact is that the electrical engineer, in building a transmission line, may make the loss in transmitting electric power over that line, practically any amount that he wishes it to be, for the larger the size of the wires placed on the poles, the less will be the loss of power in transmitting a given amount of energy over it at a given pressure. Thus he may make the loss 5 per cent., or 10 per cent., or 50 per cent., as he chooses, or, to write more exactly, he may place the loss of power in the transmission lines at such a figure that the greatest economy will result to the system, upon the standpoint of the interest on the investment in transmission lines, whether they be of copper or of aluminum, and the value of the power lost in transmission. An economic balance is thus obtained, and generally it runs in the neighborhood of 10 per cent., that is, 90 per cent. of the power delivered to the transmission lines at the power house is made available in useful work at the point of market, whether it be ten or one hundred or more miles away. To carry this principle of electro-economics a little further, one can see that the amount of power that can be transmitted over a wire of a given size depends directly upon the voltage or electrical pressure applied to the lines, hence it is in order to economize on the cost of wire, which calls for one of the heaviest items of investment in electric power transmission work, that electrical engineers have been compelled to devise appliances for the utilization of higher and higher electrical pressures as the only available means for enabling the extremely long distance electric transmission of power to become a commercial practicability.

The mechanisms by which these extremely high potentials are developed are known as transformers which are, in every power house, equal to the generators in horsepower capacity and which merely transform the safe electrical pressure of the dynamos up to the very high pressures necessary for transmission purposes. At the receiving end of the line the process is reversed and the high line pressures are reduced by means of transformers to whatever pressure may be desired in each and every commercial application.



FROM POINT VIEW A PANORAMA NEARLY FOUR MILES OF FLUME LINE CAN BE SEEN.

It is singular how the development of a profession so frequently converts seeming evils into positive blessings. Induction, the one-time bane of the electrical industry, is now the cornerstone upon which is built almost the entire structure of electric power transmission, and similarly, the maledictions which have been heaped upon electrostatics as causing untold troubles of an electrical nature, is the very agency now receiving the benedictions of engineers for having been the means that made the use of extremely high voltage possible. How this is done is interesting, even to the layman, who at least remembers that "like electricities repel; unlike electricities attract" each other. In this rudiment of electricity is found the solution of the problem of high voltage transmission, which it has taken more than a decade to learn. The troubles which have afflicted high tension transmission in the past were



THE COLGATE POWER HOUSE OF THE BAY COUNTIES POWER COMPANY.

most pronounced in winter when insulators, pins, cross arms and poles became soaked with water and electrical breakdowns became inevitable. All would have been well had even the insulator alone remained dry, but the dripping of water from its exposed portions, and the seepage along its under surfaces gave rise to electrical leakages that were the sure forerunners of trouble. But finally some one in the laboratory of the Stanley Electric Manufacturing Company at Pittsfield, Mass., suggested that possibly the condition might be improved if a rim be placed around the edge of the top piece of the insulator, so that the rain would be collected, and run off as a solid stream through a spout. This was done, and while, of course, the stream ran off in just an ordinary manner when the insulator was subject to no electrical pressure, the water was scattered outwardly as a spray when it was subjected to a high potential charge. The accompanying halftones, reproduced from photographs taken by Mr. E. E. Stark, illustrate the effect very prettily. A Locke insulator, such as that used on the Bay Counties' high tension lines, was mounted on a pin and cross arm after the customary manner, and a leaking tin can, placed on its top, gave improvised rain. The first engraving shows how the water falls in a solid stream when no electrical potential is on the insulator; the second shows how the same stream is scattered when a potential of 40,000 volts is applied to the insulator — scattered because the particles of water have each become electrified to a like polarity, and "like electricities repel." As a result, the under portions of the insulators are always dry and transmission at extremely high potentials becomes an assured and successful reality.

AT NO VOLTAGE.

AT 40,000 VOLTS.

But to resume our story, the other road referred to as leaving Dobbins goes past Lake Frances — the company's principal reservoir, and on down to Colgate, whence the transmission lines radiate to the east and the west to the various points of service. One of these lines, which is of aluminum, stranded like a rope, and barely ¼-inch in diameter, goes to Sacramento, sixty-one miles distant, and over this line energy to the amount of 3000 horsepower may be transmitted whenever desired at a pressure of 40,000 volts. Another similar line radiates in a northwesterly direction to Oroville, some thirty miles away, where power is delivered to two sub-stations and thence distributed over many miles of territory, for use principally in the operation of the famous gold dredgers of

A BIRDSEYE VIEW OF COLGATE AND ENVIRONS TAKEN FROM THE NEVADA COUNTY POLE LINE.

the Feather river district. It is exceedingly interesting to watch these huge machines in their work of reclaiming gold from the gravel and soil of both ancient and present river beds. Originally the dredgers were built to operate in river channels alone, but now the application of them has been carried to the seemingly absurd point of digging a great hole in an orchard, filling it with water, building a thoroughly seaworthy ship of a capacity of several hundred tons, launching it into this artificial mud-hole, and then together, the mud-hole and dredger work their way through lowlands, leaving behind as ashes of devastation, an unbroken trail of gravel. Every function of the operation of these dredgers is performed by electricity, from the making of artificial light to the hoisting of dippers, and the running of link buckets, pumps, shakers, gypsies, capstans, stackers and, in fact, everything. At present something more than 1000 horsepower is consumed in dredging operations in the Feather river district, and in view of the number of new dredgers which are under contract to be built along the Feather river during the present season, it is safe to say that within a year the consumption of power in this direction alone will more than triple the present business.

Other lines radiating in a westerly direction from the Colgate power house are the Marysville and Brown's Valley circuits, which also afford the connecting link for tying together the Colgate and old Yuba power houses. These lines are run at 16,000 volts and are of aluminum. In addition to these are two new pole lines also running out in a westerly direction from Colgate, each of which carries three wires to the region in and about the bay of San Francisco—these are the world-famed Bay Counties' transmission lines, of which more will be said later. Climbing the almost precipitous sides of the canyon opposite the Colgate power house, is the pole line which carries power to the Nevada county's generating station on the South Yuba river, near Nevada City, some seven miles from Colgate, and over which 1000 horsepower or thereabouts is being continuously transmitted day and night at a pressure of 23,000 volts.

THE PENSTOCK, SHOWING AIR VENTS AND SLIP JOINTS.

All these poles, and all these lines running out from Colgate present a scene that is probably without a parallel in the world. Coming down the hill from Dobbins after leaving Lake Frances, one sees the power lines before he does the power house, and their appearance is such that, with the aluminum sheening like silver thread in the sunlight, one could almost believe that some giant spider had begun to weave its web, for with the "parlor"

down there somewhere on the river side the ribs of the web radiate out across canyons and over mountains until lost in the sky lines. To be accurate there are forty-one of these lines, while the poles supporting them form a forest which, from some points of view, seems to be a very dense one. These are the main high tension pole lines and their aggregate length exceeds 500 miles, while the length of the line wires, high tension and otherwise, constituting the entire system materially exceeds 3000 miles, as has been stated heretofore.

Lake Frances has been referred to only incidentally, but in reality it constitutes a feature that, from an engineering standpoint, is very interesting. To understand it the layman should know that the amount of water applied to the water wheels in an electric power transmission plant will vary directly with the amount of electricity that the dynamos therein may be called upon to deliver; consequently when an electric car starts in Oakland, for instance, the automatic governing devices upon the water wheels in the Colgate power house, 132 miles away, instantly respond to the added burden thrown upon the dynamos by applying just enough more water to the water wheels to supply the power which the car demands in starting. The flow of water in a pipe line operating under a high head can not be stopped suddenly as one does a faucet, because the momentum of water in the pipe would burst it, hence the only way to solve the problem is to divert the stream on to or away from the buckets of the water wheel as more or less power may be demanded from the dynamos. It is for this reason that such great streams of water are seen shooting out from under the Colgate power house, clear across the river. The power of these giant streams from the tail races is not used in any way, for with the taking of power from the stream of water, its velocity is destroyed and converted into energy, while the water itself runs idly out of the wheel pit. When the dynamos are running to full load, that is, to their full capacity, a cataract of water falls from each wheel pit over the rocks into the river below, but there is no stream shooting across the river.

THE PIPE LINE IS ANCHORED IN MASSIVE CONCRETE PIERS.

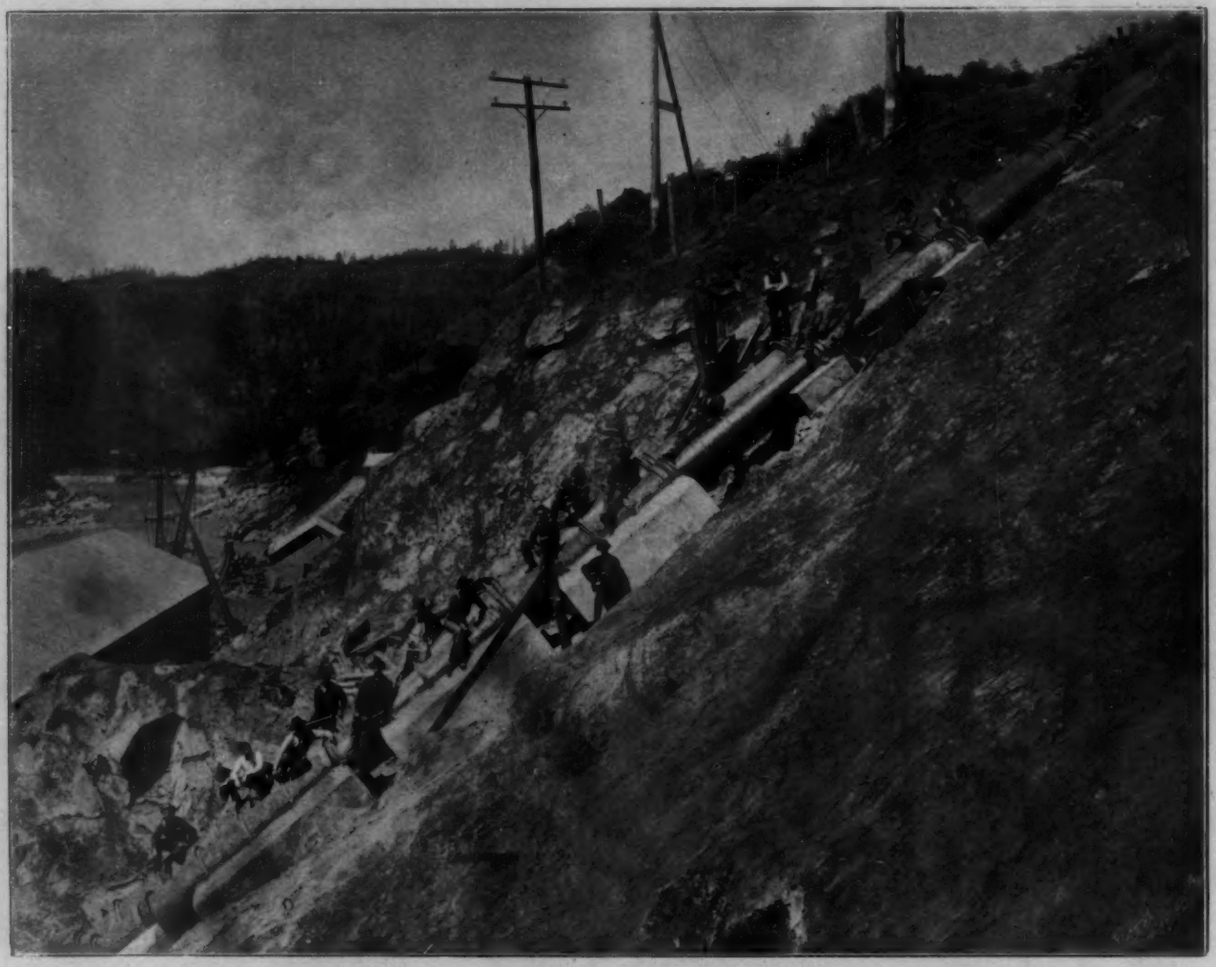
These points have been gone into thus fully that the reader may understand the fact that there is always a margin, more or less wide, existing between the maximum working capacity of an electric power house and the amount of the work which it actually does, and also that this margin must be wider when the work which the power house actually does depends upon service such as electric lighting, which is rendered only by night or for a portion of the time. The reader will also understand therefrom that in order to supply great demands upon it the electric station must always have sufficient reserve capacity in its machinery to meet any sudden calls for power, and further that this reserve capacity, although it must always be ready for use, will be but infrequently called upon for maximum service.

The existence of Lake Frances, which is the safeguard of the water supply in that it assures its permanency, is due mainly as a result of the conditions which have just been set forth. True, it is filled by Dobbin's creek during winter months, but Dobbin's creek will not maintain Lake Frances with its full storage of water, amounting to nearly 93,000,000 cubic feet, all the year round, so some of the surplus power from the power house is to be used to keep the reservoir full of water. In other words, the power house is to run part of the time on water that it has itself pumped into the reservoir. It is planned that it shall be done this way: Centrifugal pumps, run by electric motors, which are in turn driven by electric power from the dynamos when the latter are not fully loaded, take water from the flume and pump it through a line of wrought steel and wood stave pipe, some two miles in length, to Lake Frances. The electric motors and pumps are to be located in a little pumping station near the lower end of the flume, and an interesting point in the installation lies in the fact that inasmuch as Lake Frances is at

an altitude of 382 feet above the flume, it becomes a very simple matter to run the water from Lake Frances into the flume through water wheels that will drive as dynamos the electric motors which are connected to the pumps, and so give that much more energy to assist the large dynamos in the main station in carrying the load. In reality an electric motor, a centrifugal pump, and a water wheel have their shafts all connected together in one line so that when the electric motor is being driven by power from the main dynamos in the Colgate power house, the water wheel is shut off and the centrifugal pump forces water, taken from the flume, into Lake Frances. On the other hand, when the Colgate power house takes water from Lake Frances, the centrifugal pump is shut off, as is also the electric power from the motor at the pumping station; the water taken from Lake Frances is thrown first upon the water wheels at the pumping station, whence it goes into the pipe lines to the main power house and the power developed by the water wheel at the pumping station is applied directly to the electric motor with which it is connected, whereupon the motor becomes a dynamo and delivers electric power to the general system.

This very ingenious method not only insures permanence of the water supply for the main power house, but also actually enables the company to get more power out of its water than it would do if the entire energy of the water were utilized at the main power house, without incurring the waste due to running the dynamos at less than full load. The idea savors of lifting one's self by the boot straps, but it is as practicable as it is ingenious.

Geographically, Colgate is located nearly in the center of Yuba county, at an altitude of 600 feet above sea level. It is entirely closed in by mountains that rise probably 1200 feeet higher, so that it forms a community isolated by itself, so far as being on a public or even semi-public thoroughfare is concerned. The employees of the company are well provided for, however, for it has built the commodious "Hotel Martin," that is new and thoroughly modern in every respect, even to an ice machine. This latter reference recalls the stock joke among the employees of the company that the builders of the ice machine, in shipping it out to this "wild, wooly, and unbeknighted" country took the precaution to send *a barrel of brine* out with it, clear across the continent at high cost in freight charges, lest presumably those people who have beaten the world in the application of electricity in the transmission of power, might not know how to mix salt and water.



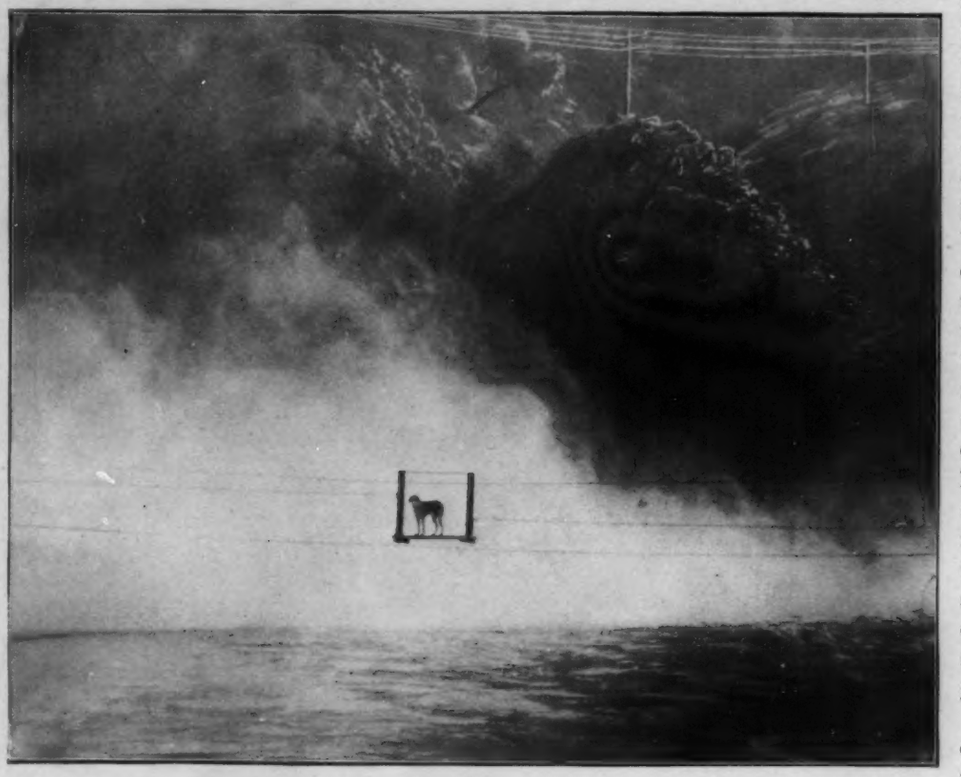
NO BETTER ILLUSTRATION THAN THIS OF THE GRADIENT OF THE PIPE LINE CAN BE GIVEN.

ENGINEER THEBERATH.

Of the hundreds of photographs which have been taken of features of the Bay Counties' system, probably none are more unique than the adjoining ones. Some wag has referred to the picture as representing "Byron crossing the Hellespont, *a la Dante*." The fact is that Byron was a favorite bird dog, whose master had come over to the Colgate power house on the "flying dutchman," leaving the dog behind on the opposite shore. The river was too swift for Byron to swim, so he howled and yelped until some of the men took pity on him and pulled the dutchman over for him to get upon. He did so and was hauled over to where his master was working. The appearance of the dog in mid-stream, with the light-load wheel discharge and the Nevada county pole line on the mountain side behind as a background formed so striking a picture that Engineer Theberath, with his camera ever handy, promptly perpetuated it.

Seven miles along the direct but impassible route of the pole line from Colgate, or twenty odd miles made up of, first, a trip across the river in the "flying dutchman," a climb up the canyon side, and lastly a drive consuming all the rest of the afternoon, lands one at the Nevada county power house on the South Yuba river. This is the third and last power house of the Bay Counties' system, although it was the first one to be installed. It seems as though it would have been hard to secure a more difficult site on which to erect a power house than that selected for the Nevada county plant, but the water power existed there, hence difficulties in installation had to give way to necessity. As it is, part of the foundations were cut out of the solid rock of the canyon side, while the outer portion of the power house is supported on piers, consisting of iron pipes carried down to bed rock in the river and filled with concrete. The lowering of the heavy machinery down the steep canyon side was an exceedingly difficult and at times hazardous performance, but nevertheless all was accomplished without accident, and so thoroughly was the work done that the plant has been in practically continuous operation since its completion, nearly six years ago. The diversion of a portion of the waters of the river into the flume is caused by a crib dam that has been thrown across the river some three miles above the power house, and the water thus taken is delivered to the water wheels under the pressure resulting from a head of 200 feet. In 1899, when the original plant was doubled in capacity, the water power was augmented by the building of a reservoir well up on the mountain behind the power house. This reservoir, known as Lake Vera, furnishes water to the power house at a head of 800 feet, to utilize which independent water wheels were installed in the power house. Lake Vera is supplied by mountain streams that are entirely separate from the South Yuba river and the lake presents an ample storage reservoir that can instantly be drawn upon in any emergency.

ON THE "FLYING DUTCHMAN."



"BYRON" CROSSING THE HELLESPONT.

Two circuits carry power from the Nevada county power house to Nevada City and Grass Valley, then besides, the two circuits from the Colgate power house also run through to Grass Valley where the bulk of the power is consumed in the Nevada county division of the company. Aside from electric lighting, by far the greatest portion of electric power consumed in Nevada county is utilized in mining work, and its applications in this direc-

tion are most interesting. In the Reward Mine, for instance, a single electric motor having a capacity of 100 horsepower runs a stamp mill, a Cornish pump and hoist; and at the Brunswick mine are two 80-horsepower electric motors, one of which drives the air compressors while the other runs the 20-stamp mill, four concentrators and one rock breaker.

The most interesting mining installation in the vicinity of Grass Valley, from an engineering point of view, is to be found in the 350 horsepower electric motor which drives the air compressors of the Allison Ranch mine. Then there is the historical hoisting equipment of the Homeward Bound mine, which consumes 180 horsepower, and the Gold Hill mine equipment, which utilizes 350 horsepower in driving air compressors and the hoist. Other almost equally interesting applications of electrically transmitted power are to be found in the Bullion, Pennsylvania W. Y. O. D., Empire, Coe and other mines, so that in all, it is perfectly safe to say that the bulk of power consumed in mining purposes in Nevada county is of the electrically transmitted variety.

GATE VALVES SEPARATE RECEIVERS AND PIPE LINES.

April 27, 1901, marks the date when the Bay Counties Power Company accomplished the crowning achievement of transmitting electric power from its great power house at Colgate, in Yuba county, to the city of Oakland, in Alameda county, over mountain, hill, valley, river and strait, a distance in all of 140 miles. Just what this means can hardly be appreciated without looking at the map. From Colgate the two separate pole lines, 50 feet apart, are carried over the intervening country in a south by southwesterly direction, traversing the lengths of Yuba, Sutter, Yolo, Solano and Contra Costa counties and advancing into Alameda county. Despite the significance of the event, it was but modestly observed by the officials of the company, with a few friends and interested parties, who rode over the lines of the Oakland Transit Company in a private car pulled by Colgate power.

To particularize, it should be stated that the Bay Counties Power Company is already supplying the market for electric power in the counties of Butte, Yuba, Nevada, Placer, Sutter, Yolo, Sacramento, Solano, Contra Costa and Alameda; it is now extending its pole lines into the counties of Sierra, Marin and Sonoma for the purpose of executing contracts that it holds for the delivery of electric power therein, and in all probability it will extend its lines into Colusa county during the present summer. In all California there is not to be found a more populous or productive region of equal size than that embodied in the territory covered by the counties named—an area of over 14,000 square miles, or practically as large as the State of Virginia. Every fruit known to California luxuriates within this district, a very material portion of the state's output in grain grows there, countless heads of stock cover its hills, hundreds of thousands of acres therein are in tule lands, which, when reclaimed by levees, are marvellously productive, the fruit and freight transportation facilities are excellent throughout the entire region, deep water shipping penetrates well into the company's market, the most famous gold mines of the state are within the scope of the company's distributing system and, lastly, aside from the city of San Francisco itself, the chief manufacturing interests of California are well within the limits of the counties named.

The public will without doubt regard the great span of wire across the Straits of Carquinez as being the most spectacular feature of the entire system of the Bay Counties Power Company, and indeed the building of this enormous span has truly constituted a wonderful achievement. Although cables for telephone and telegraph service have been laid under the straits for many years it was by no means possible to lay electric power cables there for many most valid commercial and technical reasons. The rivers of the great valleys of central California—even its entire portion between the Siskiyous and the Tehachapis—find their way to the ocean through the

Straits of Carquinez, where the tide runs deep and swiftly and where the cables are subjected to wear that would soon bring ruination to any that might carry electric power service at high electric pressures. To carry the lines overhead, therefore, was the only alternative, and the fact that there was no engineering precedent for the work proved to be no deterrent, for in truth it can be said that the system of the Bay Counties Power Company from its inception to its completion is one that has been executed without relying upon precedent as paving the way for the accomplishment of the object to be attained. Nor is it believed that anywhere in the world but in the west is there to be found the rare combination of courage of conviction, united with the daring yet prudent capital, so necessary to prove an enterprise to be independent as to precedents and resourceful as to expedients.

HOTEL MARTIN AS IT APPEARED DURING CONSTRUCTION OF PLANT.

Although the Carquinez span has been described heretofore, it is well to recapitulate that it crosses the straits between Eckley, a small station on the Southern Pacific line between Oakland and Port Costa, and Dillon's Point, directly opposite. At high water the straits at Dillon's Point have a width of 2750 feet and the government requires that any span placed above streams navigable to deep water shipping shall have a clearance of at least 200 feet. The southern bank of the stream rises gradually until, when about 1500 feet from the shore, a point is reached that has an elevation of 300 feet above high water. It is at this point that the south steel tower of the span has been erected. The north tower is located on a bluff 150 feet high at a point about 350 feet back from the shore line. This tower, which is also of steel, rises to a height of 225 feet, while some 1400 feet behind the great north tower is a third tower known as the leaning tower, also of steel, which takes a decided inclination in a northerly direction in order that the strain from the weight of the cable may be properly met. The straight line distance between the tops of the two main towers is 4227 feet, while the length of cable in the great span, including sag, is 4448 feet. If, on the other hand, it is desired to consider the achievement from a standpoint of the total length of cable, the distance between anchorages and the north and south banks should be considered, and this distance is 6400 feet, or practically one and one-fifth miles.

Some nice calculations are involved in stretching cables of this character. Four cables are used, each of which is of stranded plow steel, with an outside diameter of 7/8th of an inch, and these cables are arranged on the points of a rhombus, having 20-foot sides. The high pressure electric current is applied to these cables direct and inasmuch as the pull on each cable at the points of anchorage is twelve tons, the problem of insulating the high electrical pressure in such a way as to give sufficient mechanical strength became a very serious one, that was not solved until after months of effort. In stretching the cables they were taken one by one and laid from one anchorage place to another clear across the intervening land and water. They were then drawn into place by a steam winch, after having been placed across the saddles at the tops of the towers. It is interesting to note that when the cable has been raised so that the arc of the span just touched the surface of the water, the length of the cable between the towers was 4535 feet, and that the strain or pull of the

cable was approximately 9000 pounds. The length of the cable between the towers when the span had been drawn up to a clearance of 206 feet above extreme high water is, as has been stated, 4448 feet, and the strain approximates twelve tons. The ends of the cables are firmly secured to enormous blocks of concrete embedded in bedrock, while the metallic continuity of the cables to their anchorages is broken for electrical purposes by means of massive "strain" insulators. The south tower, on account of the altitude of its location, is but 64 feet in height, and the leaning tower, with its height of 84 feet, keeps the cables from the north tower well up into the air before being brought down to their anchorages. Never more than three cables are in use at any one time, hence one cable is always in reserve—a very wise provision—as by cutting one cable after another out of service and so using them in rotation, continual inspection and cleaning is made possible with absolute safety. Substations for reducing the extremely high pressure used on the main transmission lines to a lower pressure for commercial use, are located at the main towers: that at the north tower delivering current for consumption in Vallejo, Mare Island and thereabouts, and that at the south tower delivering current for operating the smelters at Selby, the sugar refinery at Crockett, the electric lighting of Martinez, Port Costa, Crockett and the many other applications of electric power in that vicinity.

From the south tower the main line of the company is continued on in a double line to the Piedmont power house of the Oakland Transit Company, in Oakland, a distance of 142 miles from the Colgate power house, as measured by the pole line. A pole line having a length of a mile or so furnishes the link which connects the system of the Bay Counties Power Company with that of the Standard Electric Company of California, at the Grove street substation of the latter company and through which the electric power of the Bay Counties Power Company is carried to the Oakland Gas Light and Heat Company, then on to San Jose by way of Niles and Mission San Jose, a further distance of forty-two miles beyond Oakland. Thus far the maximum distance from the Colgate power house, whence the Bay Counties Power Company is actually delivering power, is 184 miles, or just 101 miles further than ever before accomplished in regular commercial power service. More than this, the line of the Standard Electric Company is now practically finished up the San Francisco peninsula into Redwood City, where, through the medium of the Consolidated Electric

AS ONE ENTERS THE POWER HOUSE AN IMPOSING VIEW IS PRESENTED.

Light and Power Company of that city, power from the Bay Counties' system will be distributed during the present summer throughout the richly populated district between Mayfield and Burlingame, a maximum distance, by way of the pole lines, of approximately 214 miles from the great power house at Colgate.

The systems utilizing Bay Counties' power in Alameda and Santa Clara counties are by no means inconsequential. The Oakland Transit Company, which is supplied from the Piedmont and the Temescal sub-stations, embraces all the electric railway lines in Oakland, Alameda and Berkeley, with the exception of the Haywards electric railway line; the Oakland Gas, Light and Heat Company is the only company delivering electric lighting and stationary motor power service in Oakland and Berkeley, while the Electric Improvement Company does the bulk of the electric lighting and power business at San Jose, both of which companies are now using Bay Counties' power, delivered to the lines of the Standard Company at Oakland.

LOOKING WESTERLY IN THE POWER HOUSE—3000-HORSEPOWER SETS IN THE FOREGROUND.

At the present moment the Bay Counties Power Company is delivering more than 3000 horsepower over a length of line which only a brief time since was believed to be impracticable from a commercial standpoint by many engineers of eminent standing, yet the remarkable success of the installation has demonstrated that certain theoretical limitations which were placed upon the operation of such extremely long lines have no sure footing in actual practice. In other words, it has been demonstrated by the builders of the Bay Counties system that every fear, fancy and bogie of the theorist has vanished into thin air under the manipulation of the practician. Eastern electrical engineers who came out to California to witness the inauguration of the new system expressed themselves in words of astonishment that know no bounds, and one of them, himself an expert of one of the great electrical manufacturing companies of the East, summarized the situation in the terse opinion that "the system runs just as though the power house were only across the street instead of 150 miles away."

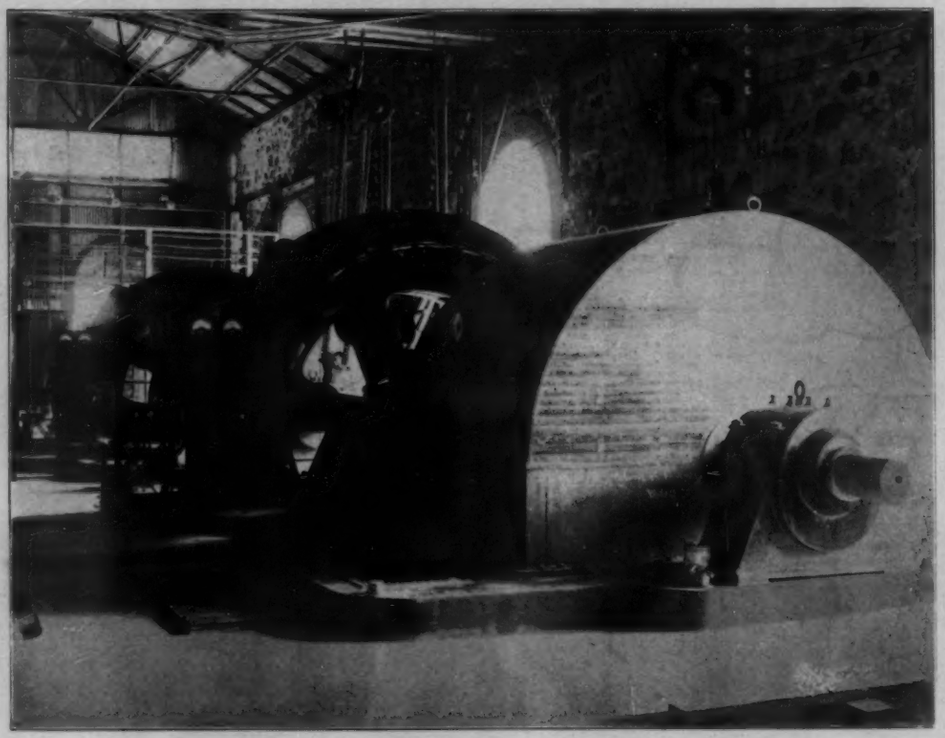
In view of that which has transpired in the successful operation of the Bay Counties' system, no engineer who is familiar with the facts will now vouchsafe an opinion as to the distance to which Sierran water power can be

transmitted and delivered in competition with steam, even though the latter be developed by burning low-priced fuel oil. There are, of course, *pros* and *cons* to the question as there are to every one, but the fact remains that electrical transmission engineering is now more strongly entrenched than ever in its ability to uphold its reputation of being the means of furnishing the cheapest power that can be obtained. As such it is the true emancipator of the industries of the Golden State.

TELEPHONE SERVICE IN CONNECTION WITH LONG DISTANCE POWER TRANSMISSION.*

BY T. E. THEBERATH.

As short a time as five years ago 5000 or 10,000 volts was considered very high potential and twenty miles almost the limiting distance of transmission and telephone service over wires strung on the power line was not always of the best. In the construction of the telephone line the matter of insulation was not considered of very great importance. Porcelain knobs or pony insulators were considered sufficient and good enough for all practical purposes. The transposition of the wires to neutralize inductance from the power wires was considered to be of great importance, and every one had his own method. Transpositions were put in every five, ten, or twenty poles, but with no regard to the current on the power line, whether two or three phase, or whether the power line was spiraled or not.



SIX THOUSAND HORSEPOWER IN TWO UNITS.

The inductance on the telephone wires is the result of the magnetic field surrounding the power wires and as the receiver of a telephone is a very sensitive current detector, whose operation depends upon most minute current impulses, it is seen at once that electrical engineers have a delicate problem before them.

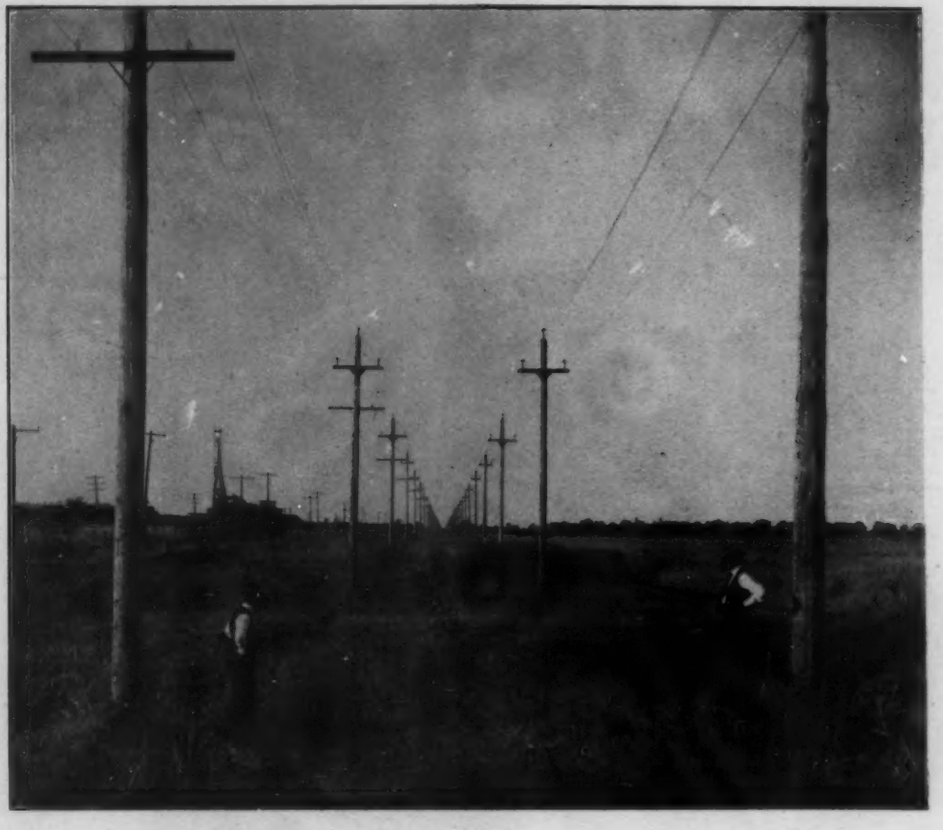
It is not the object of this paper to lay down definite rules for constructing telephone lines on power lines, but to mention some of the experiences encountered, with the hope of bringing out a discussion on the subject and of getting others started on a line of investigation which will assist in overcoming the difficulties encountered in one of the most important adjuncts to the successful transmission of power over long distances. In this paper, therefore, the experiences related will be restricted to a few lines which have come under my personal supervision and construction. The first case is a line of about eight miles in length, constructed some five years ago, of No. 10 iron wire strung on brackets one above the other on the same side of the poles, about 6 feet below two two-phase four-wire circuits, carrying a potential of 5000 volts. The telephone wires were transposed every five poles and the power circuits were spiraled with reference to mutual inductance between the circuits. The telephones were of the series type with low resistance bells, in fact, the system presented a good example of what should be avoided in telephone line construction. Placing the wires one above the other on the same side of the pole makes it almost impossible to balance the electromotive forces of inductance against one another by the transposition of the wires. The series instrument also makes it difficult to balance the line if a number of 'phones are on the same line. This line gave service but of a very unsatisfactory nature.

The next line, which was constructed some three years ago, is nineteen miles in length and consists of two wires of about No. 12 gauge, strung on the two pole pins of a six-pin crossarm 5 feet below two two-phase circuits, carrying a potential of 16,000 volts. The insulators are double-petticoat deep-groove glass, with transpositions every tenth pole, the poles being set forty-four poles to the mile. Locke one-piece transposition insulators were used, and after the line was completed it was found that the teamster who distributed the insulators was not educated to the importance of transpositions at regular intervals, and had dropped a pair of transposition insulators when-

*Submitted for discussion at the Fifth Annual Convention of the Pacific Coast Electric Transmission Association, San Jose, Cal., June 18-19, 1901.

ever he happened to think of them. The linemen came along and cut in transpositions wherever they found the insulators for that purpose.

Another amusing, as well as interesting incident occurred in the construction of this line. At a point six miles from the power house the wire was looped around the transposition insulators, leaving an open circuit in the line with two short circuited loops. It had been arranged that in case it was found impossible to communicate over the metallic circuit that both wires should be connected to one binding post and the other to ground. With the latter condition a communication was held with a party on the Sunset line. The Sunset line, however, paralleled the lower end of the line for twelve miles, but the open circuit was bridged by the power wires so that it was a case of induction from the Sunset line to the power wires (which were not carrying current at the time), and then by a second induction back on the upper end of the telephone line. The open circuit was located the following day and the error in the transpositions corrected.

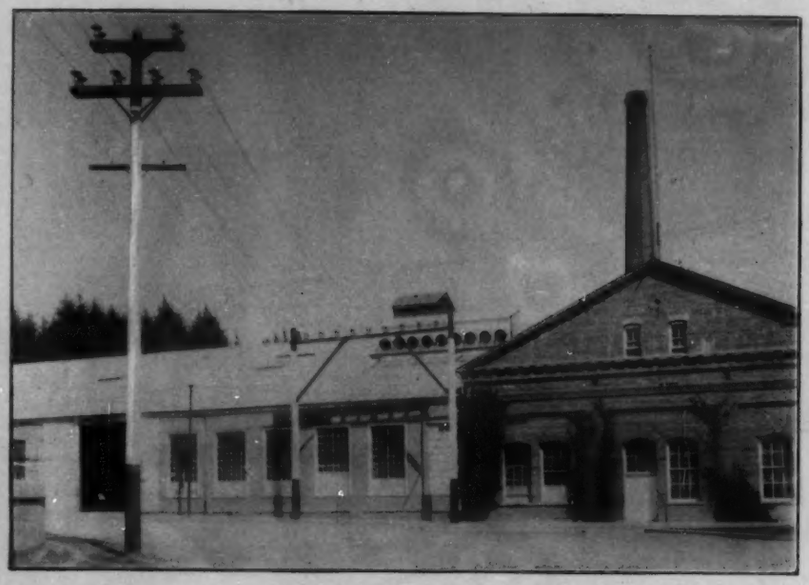


A DOUBLE POLELINE EXTENDS FROM COLGATE TO OAKLAND, A DISTANCE OF 142 MILES.

The power circuits, in this instance, consisted of two four-wire two-phase circuits for a distance of seven miles, one circuit having a half turn at the three and one-half mile point and the other going straight through for the whole nineteen miles. This telephone line gave good service, although there was a constant hum which, however, was not sufficient to interfere with the working of the line. The power line has since been extended so that the two four-wire circuits now run the full length of the nineteen miles. In extending the second line the power wires were spiralled at three points with a quarter turn in opposite directions, so as to give four divisions in the twelve miles of three miles each. This was done to reduce the inductance on the Sunset line, which was strung on the six-pin arm of this line alongside of the private line. The Sunset line was originally transposed every ten poles, intermediate to the transpositions of the private line; but as considerable trouble had been experienced on this telephone line it was finally transposed every other pole. The most benefit, however, was derived on this line when the power wires were spiralled.

This experience seems to demonstrate that the proper spiralling of the power wires is of more importance than the transposition of the telephone wires. So that in planning the construction of the telephone line for the sixty mile line from the power house to Sacramento, it was decided to try an experiment on entirely new lines. The power wires were arranged to form two circuits on the six points of a hexagon with 2-foot sides, or two interlaced triangles of 42-inch sides. This undoubtedly gives a perfect arrangement for neutrality of field, but each circuit was given one-third of a turn in opposite directions at every mile so that each circuit made one-third of a revolution at each mile in reference to earth, and two-thirds of a turn in reference to each other. The telephone line was carried through on the two pole pins of a six-pin arm 5 feet below the power wires, and without a transposition, for the entire length. No transpositions were considered necessary for the reason that the power wires were spiralled and the inductance should neutralize itself on any paralleled circuit, provided that the number of transpositions divide the line into a number of parts forming groups of four or three, depending on the line current being either two or three phase. The reason for this is obvious if we consider for instance a three-phase line, the currents of which are 120 degrees apart, and calling the wires A, B and C. With one-third of a turn each mile the A wire will occupy a certain pin for the first mile. In the second mile the B wire will be on this pin, and in the third mile the C wire will take this position. The three electromotive forces of inductance from A, B and C impressed upon a parallel wire will also be at 120 degrees

from each other and their sum will be zero in every three miles of wire. The same reasoning holds good for two-phase lines with this difference: the line being four wires, each turn is one-quarter, and it takes four miles to neutralize the electromotive forces of inductance. If a line has been definitely surveyed and is to remain of fixed length, it is a very easy matter to divide the line into an equal number of parts, in groups of four or three, in accordance with the phases. It is not always the case, however, that the exact length of the line is known before actual construction is commenced. This was the case with the Sacramento line, as well as the bay line of the Bay Counties' Power Company. For this reason the power wires were transposed every mile and the unbalanced end, if any, can be taken care of by properly transposing the telephone wires or by dividing the last end of the power line into either four or three equal parts. No attempt has been made in the bay line to correct for any equal end, but as the line is 142 miles in length, the unbalanced end is such a small fraction of the total that no serious effects are experienced.



PIEDMONT SUBSTATION OF THE OAKLAND TRANSIT COMPANY.

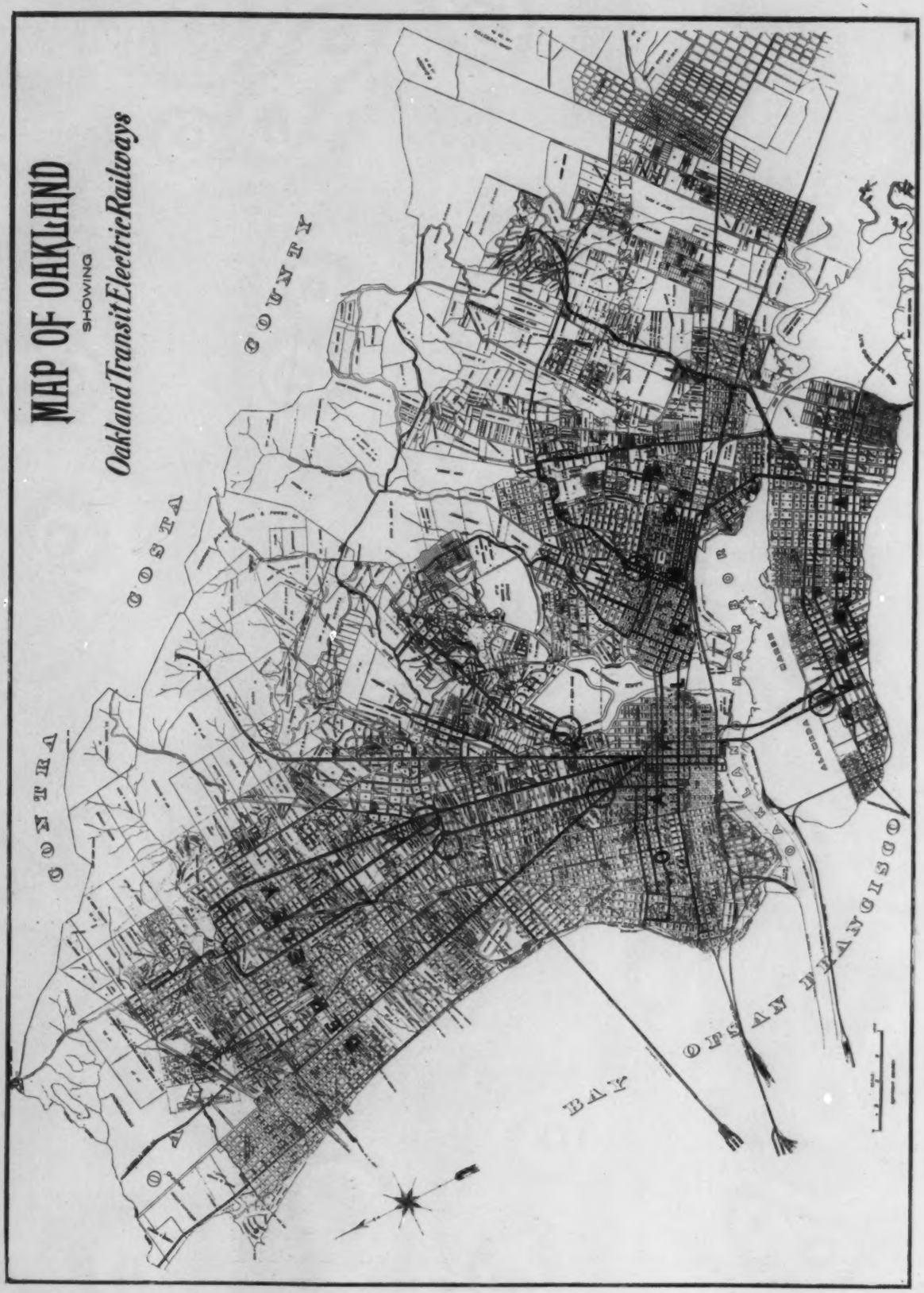
The telephone wire on the bay line is No. 4 stranded aluminum cable for a distance of eighty miles and three-strand aluminum cable for the balance of the distance. Insulators of double-petticoat, double-groove glass, on two pins, equidistant from the pole, on a six-pin arm 5 feet below the power wires, which carry current at 40,000 volts, connected with neutral grounded. When everything is in perfect order the line is absolutely quiet. Some trouble has been experienced with grounds on the telephone wires, which reduce the line at once to single-wire circuit with ground return and unbalances the line so that it is very noisy.

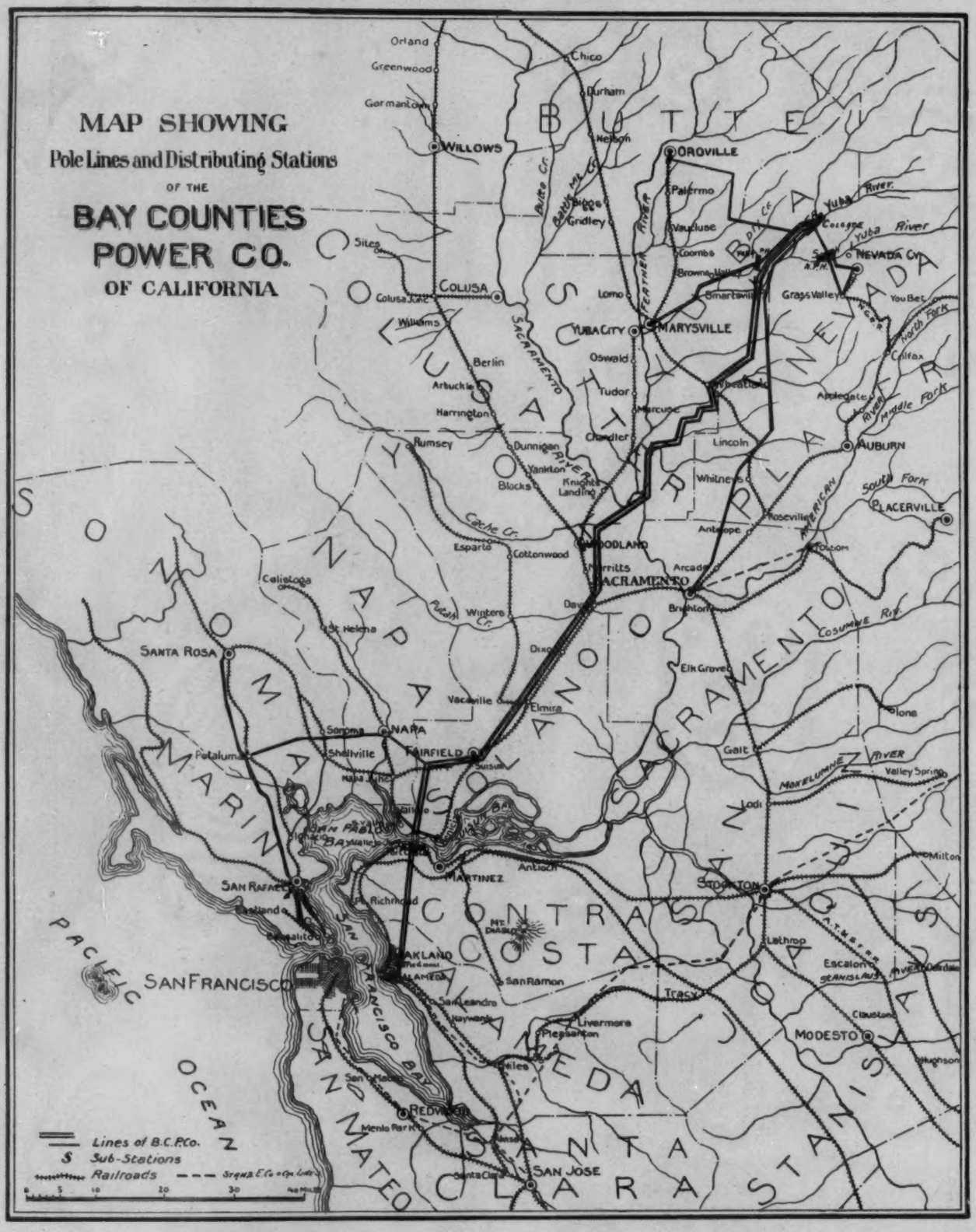
Some peculiar results have been obtained with a Weston alternating-current voltmeter on this line. The line talked very well but there was considerable hum. Connecting the voltmeter across the wires at the Oakland end no deflection of needle was obtained. From one wire to ground the reading was zero, but from the other wire 124 volts was indicated to ground. At the same time readings were taken at the power house end with no voltage between wires and seventy-two volts between either wire and ground.

These are very curious results, but any voltmeter with a finite resistance is useless in obtaining the existing conditions, as the instrument practically grounds the system when connected. A static voltmeter should be used for this purpose. Other readings were taken on other lines, but are of no further value than food for reflection to try and explain the why and the wherefore without knowing the true conditions with the assistance of a static voltmeter, or some other method of determining the voltage to earth without grounding the system.

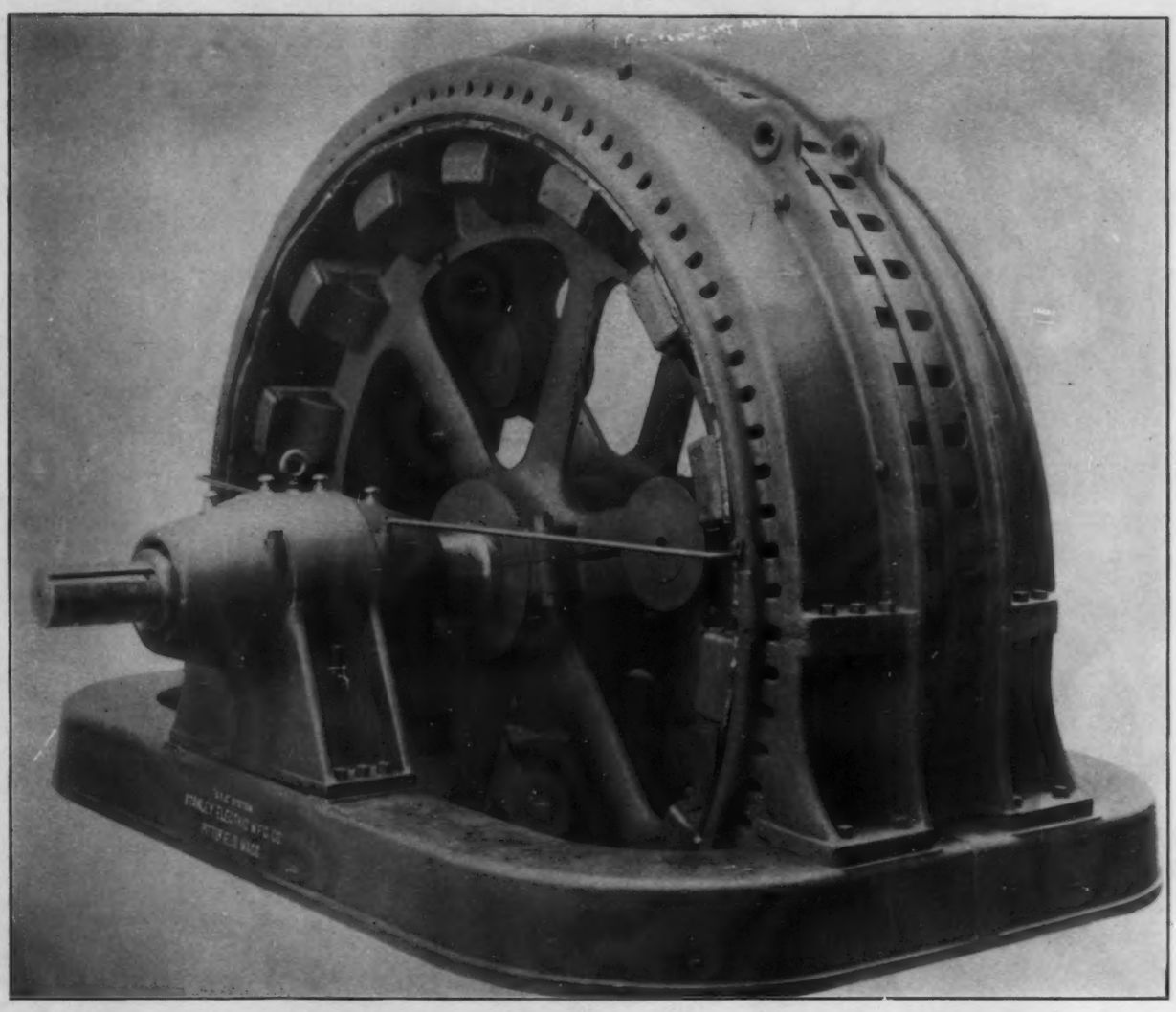
THROUGH OAKLAND A SINGLE POLE LINE CARRIES BOTH THE BAY COUNTIES' LINES.

The publication of the papers and discussions embodying the transactions of the San Jose Convention of the Pacific Coast Electric Transmission Association will be resumed and probably completed in the ensuing issue of THE JOURNAL.


MAP OF OAKLAND
SHOWING
Oakland Transit Electric Railways
CONTRA COSTA COUNTY
BAY
OCEAN


MAP SHOWING
Pole Lines and Distributing Stations
OF THE
BAY COUNTIES
POWER CO.
OF CALIFORNIA
Orland
Greenwood
Germantown
Chico
Durham
Nelson
WILLOWS
OROVILLE
Palermo
Gridley
Biggs
Butte Cr.
Butte Mt. Cr.
Feather River
Yuba River
College
Yuba River
Vaucluse
Coombs
Browns Valley
NEVADA Cy.
Smartsville
Grass Valley
You Bet
North Fork
Colfax
Middle Fork
Yuba River
Applegate
Auburn Ravine
AUBURN
Lincoln
Whitney
Roseville
South Fork
American River
PLACERVILLE
Folsom
Antelope
Arcade
Sacramento River
Cosumne River
Elk Grove
Galt
Clone
Valley Springs
Mokelumne River
Lodi
Milton
Stockton
Lathrop
Escalon
Stanislaus River
Tuolumne River
Tracy
Modesto
Waterford
Patterson
Newman
Crows Landing
Gustine
Los Banos
Dos Palos
Firebaugh
Mendota
Fresno
Kingsburg
Selma
Reedley
Dinuba
Visalia
Tulare
Hanford
Lemoore
Corcoran
Kings River
Kern River
Bakersfield
Delano
Wasco
Shafter
Arvin
Maricopa
Taft
Fellows
Coalinga
Huron
Avenal
Kettleman City
Lemoore
Hanford
Visalia
Tulare
Porterville
Lindsay
Exeter
Orosi
Kingsburg
Selma
Reedley
Dinuba
Sanger
Fresno
Clovis
Madera
Chowchilla
Merced
Atwater
Livingston
Turlock
Ceres
Modesto
Oakdale
Riverbank
Knights Ferry
Valley Springs
Milton
Lodi
Stockton
Lathrop
Tracy
Escalon
Manteca
Ripon
Oakdale
Riverbank
Modesto
Turlock
Ceres
Hughson
Waterford
Patterson
Newman
Crows Landing
Gustine
Los Banos
Dos Palos
Firebaugh
Mendota

GOLD DREDGERS ARE NOTEWORTHY CONSUMERS OF BAY COUNTIES' POWER IN THE FEATHER RIVER DISTRICT.



ONE OF THE 2000-KILOWATT STANLEY GENERATORS IN THE COLGATE POWER HOUSE.

SOME OF THE MANY DIFFERENT TYPES OF THESE GOLD DREDGERS ARE HERE SHOWN IN MINIATURE.

THE JOURNAL OF
ELECTRICITY, POWER AND GAS

Devoted to the Conversion, Transmission, and Distribution of Energy.

Conducted by GEO. P. LOW.

Official Organ of the Pacific Coast Electric Transmission Association.

Published monthly. Yearly subscription: Domestic, $1.00: Foreign, $1.50. The price of single copies is variable.

Entered as second-class matter at the San Francisco Post Office, August 15, 1899. Entered as *The Electrical Journal*, July, 1895. Entry changed to *The Journal of Electricity*, September, 1895.

Address remittances and communications to
315 CHERRY STREET, [Telephone, "Pine 76"] SAN FRANCISCO, CAL.

VOLUME XI JULY, 1901 NUMBER 7

EDITORIAL.

THE BAY COUNTIES' EDITIONS.

It is proposed that the description of the remarkable system of the Bay Counties Power Company—which has leaped by a single bound into the front rank of the world's greatest electric power transmissions—shall appear in three issues of THE JOURNAL. The first article, which appears in the present number, makes a departure from previous practices, in that it is essentially a popular description throughout. Its aim is that it will be interesting alike to the layman and to the engineer—to the layman for the purpose of enabling him to comprehend the far-reaching influences which electric power transmissions are exerting on the industrial development of the Western world, and to the engineer as prefatory to the technical descriptions to follow in the September and October issues. As to the present article, it merely gives a foretaste of that which may be expected to appear in the subsequent numbers.

THE WOOD FOR INSULATOR PINS

One of the many problems that have arisen in conjunction with transmission at high potentials has rested in the selection of the material for the pin supporting the insulator. The use of metal in any way therein, even that of a steel stiffening rod, has been abandoned, seemingly by common consent, in all high tension pole lines, and various varieties of wood, in both domestic and foreign products, has been tried with equally varying degrees of success. So, too, has almost every conceivable method of dipping, of treating, of curing, and of kiln and natural drying, been the subject of exhaustive experimentation. In view of the fact that electric transmission practice in California has now settled down to a crystallized procedure in the matter, a discussion of the properties and qualifications of the woods available for use as insulator pins is timely.

In general, a wood suitable for certain uses in certain manufacturing lines, such as in wagon building, for instance, will make into reliable insulator pins—always provided, of course, that it be properly seasoned. Several available woods are grown in California. The Valparaiso oak is probably the best oak grown in the State, and it is undoubtedly superior to most of the Eastern oaks, if properly cut and seasoned. It grows very much like the eucalyptus, or Australian blue gum tree, and is very hard to split. The white oak, as grown here, is not so good for manufacturing purposes, but it is used somewhat in house finishing, being the equal, in that respect, of any Eastern oak. Laurel has been used, to a material extent, in the past, but experience has taught that it is by no means proof against the ravages of worms. Madrone is equally palatable to worms, hence it is no longer used, although if it did not "powder post," as perforation by worm holes is called in the trade, it, as well as laurel, would be used far more extensively. Of practically all the woods, eucalyptus alone will not "powder post," for its oils and gums render it proof against worms, even against the toredo, as eucalyptus piling used by the Southern Pacific Company for years has attested.

Eucalyptus is pre-eminently the best of all the hard woods to use for insulator pins, and the species of eucalyptus known as the "blue gum" has long been grown in California, where it has attracted wide attention because of its rapid growth, stately dimensions, blue-green foliage and strikingly peculiar blossoms. For many years, however, it had no commercial value. Some, indeed, because of its rapid and generous growth, planted it as a wind-break, and a fewer number, perhaps, as a fuel supply, but there was little thought that it had any special value for other purposes. About fifteen years ago, however, Mr. T. J. Gillespie, a millman of San Jose, commenced an investigation of its value for manufacturing purposes. He erected a small sawmill in connection with his planing-mill, and during the first year procured and sawed some 50,000 feet of blue gum lumber. For some reason or other people were prejudiced against it, and sales were so small that for two or three years no more was sawed. Mr. Gillespie is an indefatigable worker, and was not to be foiled. He induced people to use eucalyptus lumber by guaranteeing for it certain qualities, agreeing to refund the purchase price if it did not prove what he claimed for it. The business then began to grow, the mill had to be enlarged, and at the present time he is supplying, not only the people of this valley, but many others in nearly all parts of the state with eucalyptus lumber for wagon poles, reaches, felloes and, in short, with all the hard-wood used in wagon construction.

In 1898 the first order for insulating pins—those used on the old Blue Lakes-Stockton line—was received, but these, being made from lumber green from the tree, did not prove entirely satisfactory. Later orders were filled from well seasoned lumber, and they have demonstrated their strength and durability so thoroughly that the electric companies which first began to use eucalyptus pins will now use no other.

The Gillespie process of treating insulator pins cures the lumber thoroughly, and although its details have not

been made public, it is known that the kiln dried lumber is not as good as that which is dried in the old and slower way of natural exposure. Mr. Gillespie dries his eucalyptus slowly in the shade, which makes the best and toughest lumber possible, and after receiving other treatments, the lumber is cut into "blanks," which are placed in a machine that turns out finished pins in a single operation.

The main lines of the Standard Electric Company of California are all furnished with eucalyptus pins of this manufacture and despite the fact that they support the largest cables known to transmission practice, and that the lines have been run under test to as high as 80,000 volts, the pins are in the best possible condition and bid fair to last indefinitely.

Years of experiment have demonstrated two facts: First, that the best lumber is made from trees growing singly, or at least in single rows, rather than in groves. This is doubtless due to the ripening and hardening effect of sunshine and the wind; the wood being more like the highly prized second-growth lumber of the East. Second, the sap-wood, or that growing near to the bark, is far the toughest, that near the center being soft and spongy, like the heart of hickory.

Certainly there is a bright outlook for eucalyptus in the near future, and he who plants the regular Australian blue gum tree will be a benefactor to wood workers and to the electrical transmission industry as well.

IT WOULD BE A BITTER PILL.

The strikes and rumors of strikes, with all the industrial demoralizations directly traceable to labor union disturbance, may lead to the enactment of legislation of more far-reaching scope than perhaps the world has ever imagined possible. Labor, and especially that of the Western Coast of the American Republic, professes to stand in fear and trembling lest the Chinese Exclusion Act, which expires on May 2, 1902, should not be renewed, and that with the lapse of this law, countless hordes of able-bodied Orientals will overrun the country, driving white labor into the sea.

That yellow labor can in time become as skilled as white labor may possibly be accepted as a fact. The antipathy of the people of the East toward the exclusion of Asiatic labor is notoriously true. What if the Eastern sentiment favoring anti-exclusion should so blend with the equally strong antipathy of American employers against the autocracy of labor that Congress, in yielding to pressure exerted, should deem the evil of unrestricted Chinese and Japanese immigration to be less than the evil of trades unionism in its present perverted forms?

What if Congress should become convinced that the unskilled Oriental labor of today may become peacable, lawabiding and skilled "free" labor of tomorrow?

What if Congress should welcome Asiatic labor as being the least susceptible of any to the machinations of the professional agitator, who is plunging trades unionism headlong to an ignoble doom?

We are sincere in the hope that time may not answer these inquiries in the affirmative, but the fear is expressed that the present attitude of labor leaders, if persevered in, may force the issue in the woefully unfortunate direction indicated.

"FAREWELL TO WATERFALLS."

It must be a gratification to engineering circles that the lay press, in some directions at least, is getting down to a reasonable measure of common sense in its treatment of technical matters. A fitting exemplification of awakening knowledge in this direction is found in an editorial utterance which recently appeared in the *Saturday Evening Post* of Philadelphia, and so pertinent are its expressions to the aims, ambitions and realizations of electrical transmission interests of the Great West, that it is well worthy of reproduction.

Under the significant caption "Farewell to Waterfalls," the *Post* says:

Electrical experts and some common people are already reconciling themselves to the prospect of the total loss of Niagara Falls as a scenic spectacle. Each power tunnel bored and returning opulent dividends to its projectors is an irresistible argument in favor of the construction of another. The cataract is like a gold mine with two million tons of ore in sight. Is it reasonable to suppose that the miners will stop when ten thousand tons have been taken out, or fifty thousand, or a hundred thousand, or any amount short of the entire contents of the load? As reasonable as it is to suppose that the exploiters of Niagara will stop with ten thousand horsepower, or fifty thousand, or a hundred thousand, or any other amount short of the entire capacity of the falls.

But while the probability that Niagara Falls may soon give place to a bare wall of rock is forcing itself upon thoughtful minds, the full implications of this tremendous fact do not seem as yet to have attracted attention. The inevitable corollary of the loss of Niagara is nothing less than the total disappearance of all waterfalls as an element of natural scenery. Niagara represents the extreme limit of the resistance of Nature to science in that direction. Long before the last drop of its mighty flood is tamed and made to flow through a turbine by way of a tunnel or a canal every minor cataract and cascade will be at work turning dynamos. In most cases the problem is elementary compared with that of harnessing Niagara.

Every little cascade in a woodland glen is a potential source of wealth. Every one may be expected to disappear, unless it be preserved in a public or private park like the surviving specimens of the buffalo. We do not yet fully realize what this means — how much the loss of the laughter of falling brooks and the surge of falling rivers will subtract from the enjoyment of life. Perhaps sentiment may be sufficiently powerful to gain for us at rare intervals a taste of the old pleasures. On a centennial anniversary or the visit of a President the masters of the dynamos may shut down most of their plants and turn on Niagara for a day. It will be a spectacle that will draw excursionists from the whole continent.

A stream that starts in the Sierras ten thousand feet above the sea may run through a hundred power plants before it meets the tide. In time all its possibilities will be utilized. Every mile of vagrant travel in its bed will be a waste of energy, and ultimately we may expect to find it running the entire distance through pipes. Hydraulic engineers will explore the remotest recesses of the Andes, the Himalayas and the mountains of Africa for sources of power, and no waterfall will be too inaccessible to be caught and tamed. What will the poets do then? Perhaps they may find poetry in a turbine, but if they do, its quality can hardly match that inspired by a cataract. And even if the poets manage to adapt themselves to the new conditions what will become of the artists? How are they going to idealize the inside of an iron pipe? Yet that is where all the flowing water will be, unless science discovers some still cheaper source of power.

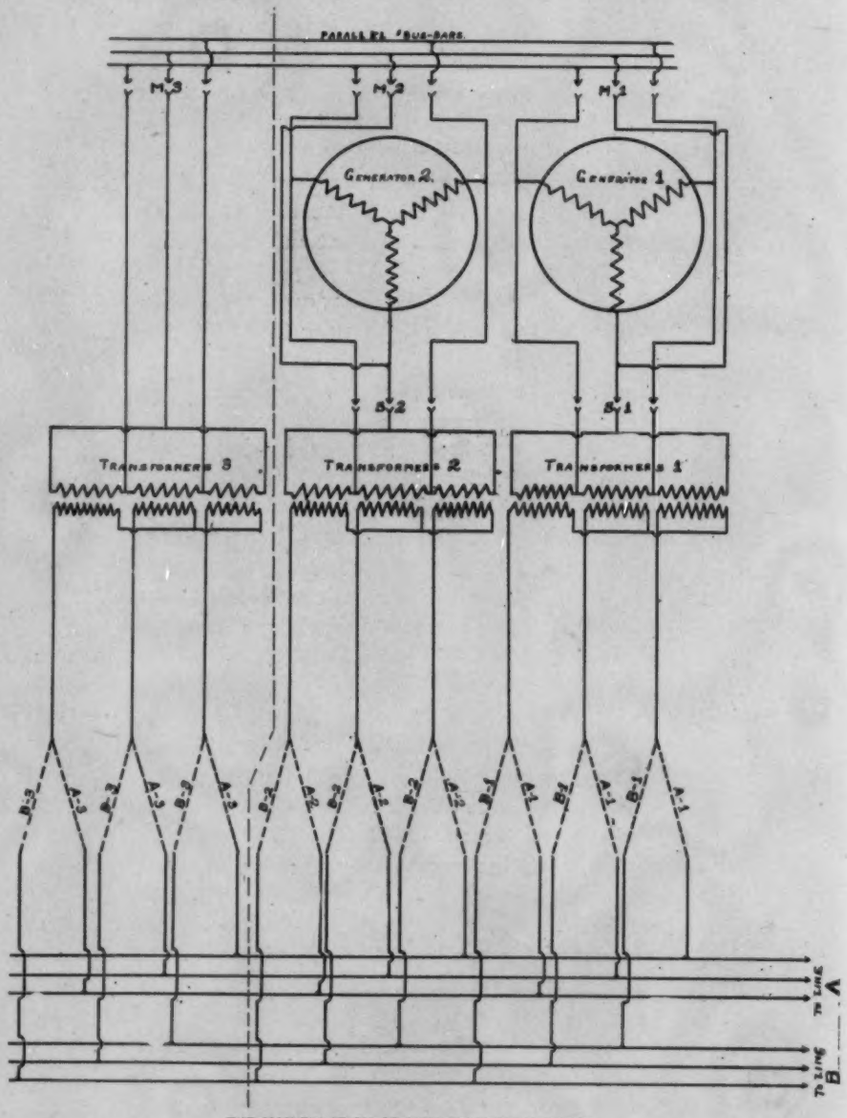
A Discussion of High Tension Switching and Fusing Practices.

ELEVEN papers deliberating upon the principles involved in high tension switching and fusing, as practiced in electric power transmission service at various potentials up to 60,000 volts, together with descriptions of the various types in use, and experiences had with many of them, were presented for discussion before the Fifth Annual Convention of the Pacific Coast Electric Transmission Association, recently held at Hotel Vendome, San Jose. These papers, with the numerous illustrations which accompanied them, appeared in full in the June issue of THE JOURNAL, and below is given the discussion which was held upon them in open convention:

Mr. de Sabla in the Chair.

MR. POOLE. I should say, in reference to Mr. Masson's paper, which is a very able one, that I agree with him that high tension switching should be done on the low tension's side, wherever possible. We make a practice, before throwing our high tension switches, to be pretty sure that the low tension switches are open, and find it works very well indeed. On two or three occasions we have tested the switches we are using, and had some very beautiful pyrotechnic displays. We have not been able to photograph them yet. They are very beautiful. To my mind it seems quite possible that extremely high tension switching may be done in submerged switches. There may be an elastic limit to the carbonizing effects of oil, and things of that kind, but if you can get a liquid of some kind—good, pure water, or something of that kind—properly encased, it seems to me we may look forward to something of that kind in high tension work.

MR. MASSON. In this little diagram is shown the general plan that is used by the Independent Electric Light and Power Company, with the exception that this is shown as a three-phase plant, instead of being two-phase. The general idea was to have a system of holding generators in multiple on the low tension side, while putting in the high tension switches in case of putting them parallel. For that purpose we have special busbars on the switchboard, with switches going from the low tension side of the generator independent of any circuit breakers or switches which throw the generators on to the transformers. That avoids the old trouble of having something like double voltage on the high tension busbars at the time of throwing in or out the first switch in an attempt to synchronize or separate them. In most high tension work we have had single pole switches in this country. Back East they are using three-pole switches, which helps that a little; but it is very much better, if you have two machines out of phase, not to throw in one leg of the circuit, because when you do, if they are passing over the waves, they produce double voltage when they are at opposite points. In the same connection we have arranged in our plant to open and close all high tension switches when there is power on both sides of the switch, so we never have a spark unless a man gets mixed up (which he some times does). If we throw in the multiple switches, shown at the top of the sketch, and marked "M," it holds the machine in multiple with the other machine, which is supplying the line. The two machines being held in multiple on the low tension side, current supplied to their transformers through the switches at "S," there is no potential difference on two sides of the open high tension switch. That switch can be closed and opened without any spark at all. The shock that is produced in any case by a spark is a bad thing, and while it certainly is possible to make a switch that will open any circuit (if there is a big enough building around, or provided we want to use oil, in which case the spark is very short), we cannot remove the shock on the insulation which is due to opening the circuit. No matter whether we break an arc in the air with a gap of 6 feet in a long flaring arc, or in oil with a gap of 3 inches, we are still producing the same shock on the insulation. I believe that it is a question of time, rather than insulation, when the results will be serious. I find that in sub-station work it is very nearly as easy to do the same thing. If you wish to throw in a bank of spare transformers, it is a very easy matter to put the low potential in first, unless the transformers are working on a separate job in their own station.



THE MANIPULATION OF HIGH TENSION-SWITCHES.

In that case, if it is not too much complication, I believe—of course, you couldn't do it with a large plant, but with some of the smaller plants we could even afford to clear a line away back to the power house and start our first bank of transformers from the generator end instead of throwing them in on the line. Where they are working in multiple on bus-bars, as they usually are in sub-stations, it is merely a matter of closing the low tension switches first, and then closing the high tension switches. The effect on lightning arresters is very remarkable. There is a little experience up the country on the Truckee General Electric Company's plant, in which case they insisted on opening the main line switches. They have a very peculiarly dry atmosphere up there, which gives them an extra heavy static charge on the line, and those switches, which are the M-T type, did not open the circuit very well, and, usually, didn't open at all. A switch is always limited to what it can do. It is never definitely certain that a switch will open any particular circuit. It is only a question of its opening a certain number of amperes at a certain voltage and power factor, and if you increase the bad condition on the line, it doesn't make any difference who made the switch; it is not going to open the circuit. They opened the lines every day or two to see that the switches were in good working order, and nearly every time that they opened one of the lines, without load, the lightning arresters broke down under the strain. I think they were what the Westinghouse Company call Type R lightning arresters, and as they continued to break down, of course there is no question of the results. They were of non-arcing metal, and the surface became burned, and after a time there was short circuit across the lightning arresters. I believe that after they got through with the last experiment they made in that direction the arresters stayed short-circuited, and they are now buying new ones. It shows a very bad plan of action to try these high tension operations and I believe that a plant would be the better if we didn't try them at all. Every insulator on the line, and every bit of transformer insulation is being tried in a manner which is very similar to the old scheme of testing a boiler for break-down pressure by putting on two or three times the full steam pressure, thereby straining everything, and then when they do go to work under the regular strain, they will break down. One plant ran for two years and three months with loads varying from a full load to 25 or 30 per cent. overload for periods of seven or eight hours each day, without any transformer difficulties. They didn't have a spare transformer, and they didn't have a spare coil. They did not have a spare lightning arrester, or any lightning arresters. They ran without lightning arresters, and without switches. At the end of this time they became prosperous and wanted to get some spare transformers and coils. They bought two transformers and put one at each end of the line for fear they would have a breakdown, and I think it was about eight days after they got the spare that they had a breakdown. They had several breakdowns within three or four months. When they got the spare they wired it up and put in switches to throw it into circuit right away, and they had tried those switches perhaps a dozen times to see if they could make this connection rapidly under working conditions, and the results were very certain. They could make the connection, and they had use for it right away.

MR. MARTIN. I think any manager who would overload his transformers to the extent of 15 or 25 per cent. was using bad judgment. I think if the transformers were not subjected to more than a normal load there would have been no trouble.

MR. HUTTON. One question I would like to ask, Mr. Masson, and that is, taking that diagram, say the right hand figure there, you said something about when you put in one switch you get double voltage. Take that right hand figure, and supposing we put in the switch on the bottom, how do you make out the double voltage?

MR. MASSON. I would like to refer to this point that Mr. Hutton makes. In the diagram, if you have No. 2 generator running on the bus-bars, the normal way of throwing in No. 1 generator would be to close the high tension switches first. That eliminates the question of double voltage which I spoke of, but it gives this effect, that your high tension side of this bank of transformers is unequally changed, or at least, it is changed from a single leg of the high tension circuit, which, in turn, produces a charge on the low tension side of this transformer, and through the synchronizing lamps which span the gap S1, that static charge is thrown back into the generator. It is very bad to have a static charge go in on a circuit of that sort, and different devices have been used to stop the bad effects. Among others is the Westinghouse spark gap, and a similar device, used by several companies, of putting lamps from the center of the transformer to ground, or of grounding the center of a set of transformers of this kind. That static charge is what I was trying to eliminate, and that is eliminated by closing the S1 switches from the generator side, and sending the high tension current up the other way through the transformers.

MR. POOLE. I would like to ask Mr. Masson if properly constructed lightning arresters will not act as a safeguard against those extreme high voltages produced by the static effects?

MR. MASSON. A properly construced lightning arrester—(I don't know how much you can get for actual figures) but you can stop this rise in static voltage at some number of times the normal voltage; say, twice. On an ordinary 15,000-volt circuit it takes about 30,000 volts to break down most of the company's lightning arresters. Some of the manufacturers get a little better than that, and some a little worse. But if we are running at 15,000 volts, it would be much better not to raise the voltage to 30,000 until necessary. In working the static voltage does go above the normal, because it passes over the lightning arresters pretty nearly all the time, but it is in a balanced condition, and doesn't seem to have as bad an effect as that which comes on a single side of the circuit. So, while the lightning arresters might protect against this rise in voltage, they would not stop short of about twice the normal voltage, and it would be much better not to produce that strain of twice the normal voltage if we could avoid it. Another thing: the lightning arresters which are being used are being worn out. A lightning arrester is at its best if not employed at all, except to stand around and look out for lightning, and if we work it on every-day discharges due to the static current, we are using it much faster than we need to use it with the number of lightning discharges that we have, and they are very few. I think lightning arresters on this side of the mountains often have not passed anything more than a fine static spark for two or three years. I think a lightning arrester is a machine like an arc lamp; it wears out; it is used up by the passage of the current, and it would be better not to have these passages, in order to keep the lightning arresters in first class condition.

MR. STARK. I would like to ask what suggestion he has for putting in, say, a switch that is loaded or charged for putting in a bank of transformers on those without the use of the high tension switch? I don't see how it can be done.

MR. MASSON. If it is a single bank of transformers, situated in a lone substation, or if, for any purpose, the substation is cut out, and the line is working, there is no other way but to throw it in. There are very few substations with but one set of transformers. We have them in the pumping plants. There the transformers can be left in, as far as ordinary practice is concerned, for an indefinite period. I don't think it is advisable to take them out when you don't want them. In a water power plant, particularly, I would suggest leaving them in at all times, because, when they are not working there is usually plenty of spare capacity, and a little iron loss does n't hurt anything. That would apply to the single bank stations. We could probably leave those transformers in indefinitely, unless there was some actual trouble in the substation. In all these cases, I think that the question of repeated strain is the important one. If we do this thing once it is all right. It does a certain amount of harm. But each time that we do it, it does the same amount of harm, and perhaps a transformer would stand a hundred "throwings in," or a thousand, but if we use the switches we are going to arrive at the time when they

break down much quicker than if we leave them in, say a month, or six months, or a year, without opening the switches. In all stations where there are two banks of transformers on the same sort of work, there is no trouble whatever in throwing them in on the low tension side, and then reversing the operation to take them out. An exception to that is the case where the two lines feeding the substations are not in synchronism. But I think that should be avoided in operation as much as possible. It has the same effect on line insulation to run two separate three-wire lines out of synchronism that it has on the switchboards that I referred to, for the reason that if any one point on the line happens to be accidentally connected to one point of the other line, either through a leaky insulator, or in any other way, we immediately get the double voltage on the other insulators of the line, and will probably break them down. I think that in regulating a plant, if the plant is fortunate enough to have two lines, so that they can use one for lighting work, and one for power work, it would be better to run them in multiple on the generating station end, if it does not disturb the voltage too much by the speed regulation of the generator. In general there is very little trouble in leaving the lines in multiple at the generating station end since the greatest part of the disturbance occurs beyond that point.

MR. STARK. Where would you advise the fusing of high tension transformers, if they are not to be disconnected from the line?

MR. MASSON. Fusing is a bit different from switching. If you put on a fuse which will not blow by resistance through the contacts, there is no serious effect from the static charge of the line, because, when the line fuses it is always connected to a very heavy load at the other end of the line, and if the line is connected to anything at all, even a single bank of transformers, you seldom have any evil effects from switching, and in the case of fusing it is accompanied by a very heavy arc, which lets all of the static charge down before the arc discontinues, and the very fact that it is fusing or short-circuited shows that there is no possible static charge at the other end. I think in small stations fuses are a luxury, and it has been my custom to make them so big that they never blow. We have had to sell them to a man because he insisted on it, but fuse them up so they cannot possibly be blown, and you have the best possible condition, except in large plants where the discontinuance of service at one point cannot be allowed to interfere with the other. In those long lines they will have new reasons for putting in fuses, but in the small plants it is very much better not to have any circuit-breakers or fuses at all. The Independent Company is now operating all the way to the substations without any automatic devices at all. We have locked up the circuit-breakers between generators and transformers, and we never have opened the circuit-breakers between the switchboard and the cables. In that case it was the same thing. We didn't dare let them open on no load. We might have used fuses there, but circuit-breakers we could not use, because they are likely to jar out in time, and our cables were not made to stand opening a 11,000-volt current when the other end of the cable is open. So our circuit-breakers have been tied in on all the underground 11,000-volt service. Our overhead circuit breakers are working very satisfactorily because we have not blown them out, but I don't think that fuses on high tension circuits or on any circuits, low tension or high tension, should be employed, unless it is absolutely necessary—besides, a man ought to think about four times before he allows a fuse to blow. It is safe enough to use fuse to take care of a very heavy short circuit, and in all of our distribution work the fuse tables that we use have for motors about four and one-half times the full load current, for lights about twice the full load current, and for arc lamps about three times the full load current. In the month of May, by the use of these tables, we blew eight fuses altogether, including about 2000 service fuses, and all of our station apparatus. Of course, on the short circuit distributing lines we have circuit-breakers which must be used, because the elevator man usually short-circuits his elevator about once a day, hence we must have a circuit-breaker for him, but that is set for a dead short circuit, and does n't go out at less than about five or six times the full line current.

MR. HUTTON. Speaking about circuit-breakers, and the high tension line, on our Sacramento plant we have four circuits between the generator plant and the substation, and we operate them all in parallel. Very often we have trouble with one circuit and, of course, it shuts the whole thing down. I have been figuring on using the same that they are using at the Niagara plant, that is to have circuit-breakers in at the generating station, and reverse current circuit-breakers at the substation. I think you had the same layout when you started. That was the intention.

MR. MASSON. That was the intention.

MR. HUTTON. The trouble you have is on account of having a cable. If you have transformers connected with the cable, the transformer will suffer, and if it is the cable, the insulation of the cable. High tension lines on poles is a different proposition. I can illustrate it this way: take the back of this chair. Eliminate this one round. Here is the bus-bar at one end, and a bus-bar at the other. We have these four lines. We have a time element circuit-breaker in here on this line, cut in between the line and the bus-bar, and a reverse current circuit-breaker here. In case of a short circuit on this line, this short would be dead, not only through this circuit, itself, but also in multiple around this other way, and up through this line upward. With the reverse circuit current-breaker in here, the moment the current started back, this line would be cut out. At the end of three seconds' time this circuit would be cut out entirely. If that short would be cleared in three seconds there would be no shut-down at all. I would like to know if there is any reason why these would not work all right?

MR. MASSON. I should say they were certainly the thing to put in. You are clearing the line which you are not afraid of breaking down.

MR. HUTTON. How about transformers?

MR. MASSON. That does not affect your transformers, because you have your transformers fed by something else.

MR. HUTTON. Where the transformer is fed in the middle of that line?

MR. MASSON. You will have no trouble with those, because you let them out.

MR. HUTTON. Suppose I have transformers fed off of this circuit in the middle of the line and this line becomes shorter? Of course, I have only load amperes on this line, due to that short. The instant those amperes are shut down, the field they will set up will induce a voltage. Will that damage the transformer connected to that that is feeding the load?

MR. MASSON. No. But you should have a three-pole circuit-breaker—not a single-pole circuit-breaker. If you had three single-pole circuit-breakers you might have trouble.

MR. HUTTON. If it is cut loose from this end, and two of them cut out at this end, it is practically dead anyhow.

MR. MASSON. It leaves one leg of the transformer on, and wouldn't give any trouble. If the circuit-breakers at the two ends were likely to jar out, or go out by accident more frequently than your line was likely to break down, I wouldn't use them. I would tie them in, like I did ours. Circuit-breakers are very treacherous at best; you can't tell whether they are going to stay in or not. You must have them set by hair trigger, and hair triggers are bad things in an electric place. I believe in a water power station, that it is better—that is a very general statement, but usually better—to shut the plant down every time you have trouble, provided your troubles are not too awfully numerous, than it is to use automatic devices; that is, for small electric plants. I am not talking about these 140-mile plants, because they are forced to use circuit-breakers and all sorts of things, and they will have to develop new lines of apparatus to do that. The Standard line won't help their case at all. They will have to have a circuit-breaker that does not jar out, and is not set on a hair trigger, and they will probably be able to tell us more about that than we can guess at present.

MR. STARK. I think that Mr. Hutton's first assumption that

the lines are short-circuited that has caused the trouble, will answer that question in regard to the transformer. If the line is short-circuited, the transformers are short-circuited, hence there cannot come any trouble.

MR. MARTIN. All I can say in regard to the Martin switch is that it was originally designed, as outlined in the paper, for use on 16,000-volt circuit, 19 miles in length. A test which would bring out every point that Mr. Masson was speaking of was made by Dr. Perrine, showing the capacity of discharge of local line. At that time the potential was increased to 36,000 volts by placing the two banks of transformers in series on the high tension side. The arc was dissipated quite satisfactorily in less than two seconds, and the photographs are very much over-exposed which gave us the result. Those switches have filled a certain purpose in the transmission field. They have not been designed for excessively high voltages for the reason that other devices are more suitable. For 5000 or 10,000, or 15,000 volts they have been very extensively used. In Nevada county there is one switchboard containing 64. They are very generally used on synchronous motors where the motors are on 5000 volts, and where you frequently would get 5000 volts if the motor was thrown in out of synchronism. They are standing the test of time, and probably are as useful in their way as most any other switch. I would be glad to answer any questions that might be asked. The switch, which is back of the board break, we extended iron arms for the purpose of getting the bearing somewhat distant from the middle. We eliminated that by lowering the bearing at the middle that much longer, in order to support the weight of the rod.

MR. LIGHTHIPE. I have seen the switch, and I understand it works very satisfactorily. I have seen a great many of them in Nevada City. We have our own switch. The General Electric Company is following distinctly an oil switch for high potential and all heavy circuits. The latest pipe that we are using or experimenting on — it is not quite standardized — is a 40-volt switch, which we are trying on the Kalamazoo plant. I understand it has gone through satisfactorily. We have been creeping up on our high potential switches from 10,000 on up. When I was East last year they were working on a 22,000-volt switch, which has since been standardized, and I think we will soon have a 40,000-volt switch on the market. As Mr. Masson suggests, if you have plenty of sky room you can open anything, but as a rule we have not room in the station, and the very trouble with the high potential switches on the Truckee station and the Truckee substation, or the Comstock substation, is the lack of room to work those switches. I think they are afraid to use them entirely. Where you can open a high potential switch in a very confined space, and be sure of smothering it, I think that is the future switch for high potential work. The switches that we are using on the Metropolitan Railroad are not very high, but they open very heavy circuits, and each switch is single-poled and confined in a brick fireproof vault, and works pneumatically, and they have stood the test of time very well indeed. The switch in the Metropolitan station is probably 80 feet away from the man that operates it. The chief operator at the switchboard operates a lot of baby knife (?) switches, which operate all the heavy stoppings in the fire-proof vault, and they have had absolutely no trouble at all in switching 5000 or 6000 volts, and as high as 3000 or 4000 amperes. The arc is broken instantly by being submerged in oil, and it is, in my opinion, the future switch for all high potential work. We cannot afford to have an arc that will carry 9 or 10 or 12 feet in the air, and you don't know what it is going to hit. We found that out in southern California when we attempted to open that open switch, where we had a short, and the arc simply sizzled all around that roof, and we had to short circuit the entire line to the several substations, and the question of opening the switch — we may open it or close it a dozen times and see nothing very serious — but opening the switch at a certain critical part of the wave, you will have fireworks that is going to set something afire if you haven't got plenty of room, and we haven't got the room for any 30,000-volt switches in any substations I have seen. I don't want to criticise any switchboard, but I would very much dislike opening the switches at Piedmont on account of the proximity of that corrugated roof. I think a 30,000-volt switch open, or 40,000-volt switch opened with a load on, would carry an arc 10 or 15 feet long, and if she hasn't got plenty of head room to break, she is going to catch on to something. It don't take long to make a hole in the roof, either. I think the future development of all this high potential work is to confine them in a small space and bury all the breaking parts in oil — submerge them in oil — and break them out of sight.

MR. MASSON. There are some figures on that subject that were interesting to me the other day, made in a test in breaking a 2200-volt current. It shows what the proportions are. I broke 125 amperes, 2200 volts, with an experimental switch on a $\frac{1}{16}$th-inch break; broke it 200 and some times. I tried it a while myself, and then got a boy to break it 200 times, and the actual opening of the switch was blocked off, so it could only open $\frac{1}{16}$th of an inch. It was 125 amperes, 2200 volts, broken by a $\frac{1}{16}$th gap in ordinary transformer oil.

MR. POOLE. I haven't very much to offer, only what I have said. I repeat what I said before, that my idea is that the switch for high tension work will eventually be submerged in either oil or some other liquid. Mr. Lighthipe's suggestion that you require plenty of room for opening the switches in the air I think ic very well taken, but I can say that we have opened one of our 40,000-volt switches, carrying 42,000 volts experimentally, and the arc was very pretty for a time, about as large around as your arm. We thouget it worked very satisfactorily indeed. That was done without having the fuse enclosed in a non-arcing substance that the Standard Company recommends for that; simply done in the open air method. I think that it is possible to break those arcs at 40,000 volts. I think it is done very successfully, but if it can be done neater and more safely in some kind of liquid, I think that is the thing to look forward to.

MR. LIGHTHIPE. The question of a switch working very satisfactorily will lead to a great deal of danger. You can open a switch a dozen times without any great fireworks, but you will open it once too often when the line conditions are such that you will have all the fireworks you want to see. You can open and close the switch a dozen times without meeting any disastrous effects, and the thirteenth time she will go all to pieces. You want to skip the thirteenth time.

MR. A. H. BABCOCK. I may offer a personal experience in the line spoken of; approximately 26,000 volts. The arc was caused by a man backing into the wire, and the holes in the roof showed very plainly where the arc had followed him as he rolled down the roof, and the lowest hole — the farthest away from the wires where I took his body away from — was approximately 8½ feet from the nearest mark that I could find on the line. That simply indicates that the arc followed him for that distance. It was a 26,000-volt arc, so I came to the conclusion that an arc can wave around for a very long distance on a comparatively low potential. I say low potential, alongside of 40,000 or 60,000.

MR. MASSON. The character of the load that Mr. Babcock mentions is extremely important. In opening these cables on a current of 1⅓ amperes at 10,000 volts, which to you people is extremely low — we have made an arc that reached up from a switch 6 feet high. The character of the load solves the entire question of the length of the arc.

MR. THEBERATH. So far it seems that the discussion has brought out that the natural trend is to an oil switch. At the same time, another question was brought out by Mr. Stark's question in regard to fuses which seems to be illustrated in the line of the Standard Company, and that is, the arc is open through a fuse. In other words, a switch using a fuse as the opening point would seem to indicate that it would protect our transformers. At the same time an oil switch would probably perform the same office if there is any protection of the insulation of the transformers, from the fact that an arc may exist for a certain length of time, and eventually be choked off by the oil so as to give the line sufficient time to discharge through the arc, and not puncture the insulation of the transformers. My opinion is, that in the very near

future all high potential switches will be oil switches, and it would be well for the manufacturers to look in that direction. Opening a switch in the air, as Mr. Lighthipe says, requires too much outdoor room, and when we consider a substation taking current from a high potential line, and figure on the cost of the building in order to install the lightning arresters, and the high potential switches and so forth, we have a building about four times as large as that which would be necessary to accomodate the transformers. This can be eliminated by an oil switch.

THE CHAIRMAN. Wasn't that the experience at Colgate, a 2000-volt switch on a 2000-kilowatt generator, on a short circuit?

MR. THEBERATH. Yes. We have opened a short circuit on 60,000 volts, on a 3000-horse power generator on the low potential side, however, with an oil switch. The current at the time was away above the capacity of the generator. In another instance we opened the switch under a load of 500 amperes under oil at 2400 volts, and instead of causing the switch to open suddenly, as you would with the switch in the air, we found the best way to open an oil switch is to open it very slowly, giving the oil a chance to dissipate the arc before getting too much distance between it; in other words, keeping the arc as short as possible instead of lengthening it out by a quick movement of the switch. The first time that it was opened it was opened very quickly, and an examination of the switch indicated that the arc had been drawn out so quickly that the oil did not get a chance to get in between the contact points, and it burned the contact points slightly. However, when the switch was opened slowly the points were saved absolutely; no indications of any burns at all.

MR. STERLING. We did a somewhat similar thing in Oakland the other day. We had a switch, about 2500 volts, in the neighborhood of 600 or 700 amperes, a pretty good overload on the switch, and the switch on a 200-kilowatt machine, and that switch dropped out by its own weight. The first small break comes out very slowly. There was not the slightest trouble; we never saw any trouble. It worked very satisfactorily.

MR. POOLE. It would seem, from some experiments that I have made on insulating oils, that it points to something other than oil for the insulation, or, rather, for the liquid that breaks the arc on extremely high voltages. I have noticed in testing the transformer oil and switch oil in closed receptacles where it could be watched very closely, that separating the terminals to give 28,000 or 34,000 volts, that it will break across and carbonize the oil very rapidly, so that you can see the black streaks in it, and it would seem to be quite possible for those extremely high voltages to carbonize that oil sufficiently to establish an arc across the voltage.

MR. MARTIN. After listening to the entire discussion it seems to me that there is no necessity for throwing a high potential switch at either the substation or generating station unless you have a short circuit on the high tension side of your transformers. If that is the case, they will be used merely in cases of such an emergency. Consequently, if you had a transformer which is short-circuited on the high tension side, you will have nothing to protect, because the property is being destroyed anyhow. If, on the other hand, you have a short circuit on your line, and you are driving either by steam or motor wheel, you do get an increased current on the line and the water wheel, due to the slowing up of the engine, so that in case you are supplying motor circuits, it would be a very simple matter—probably the time element being less than half a minute—to isolate that particular circuit on one machine rather than have the entire energy from the station pumping into that one short circuit, and in that way you can control it. So that the necessity for throwing the high tension switches, to my mind, is in a remote manner for the purpose of throwing out a bank transformer where the high tension side is short-circuited.

MR. THEBERATH. I would like to disagree with Mr. Martin on that remark. We have cases where we must operate high potential switches; for instance, in the case of the day line, we have two circuits which are put in as a safeguard for continuous operation. In case of trouble on one line we have to be able to switch over on to the other line and transfer on the high potential side, whether there is a short circuit or not, regardless of the transformers. Furthermore, in connection with the long line, duplicate line especially, there will be a time when the load will be so heavy that both lines will be required, and possibly some repairs are to be made at some section of the line, and by introducing switching points at, say, two or three points in the line, we could cut a small section of one of the lines out of service and make the repairs and still have the balance of the duplicate line in service. In that case we would have to do our switching on the high potential side, and high potential switches are necessary and will have to be manipulated.

MR. STERLING. I agree with Mr. Theberath on that score. You take this case, for instance: We have coal burning, and in one instance it burns three or four hours. We have plenty of time, if our spare circuit had been completed in time, to have thrown that off, and thrown the defective circuit out without any interruption of the service. Mr. Martin just suggests, why not open the low tension side. That would interrupt our service and throw the motors out of use, so we have to have a switch that we can open and take care of.

THE PRESIDENT. How would you answer Mr. Lighthipe's remarks in regard to opening the switches?

MR. STERLING. It is really an unknown quantity with us. We protect our switches very thoroughly, we think, with asbestos, and we are waiting to see the fireworks when it does happen. We are relying a good deal on the small tubes, through which the arc has to be blown, which, I think, in great measure, will dissipate the arc and blow it in line with the arc of the switch, thereby relieving the danger of the arc bounding to the iron roof, which, of course, is an element of danger in the Piedmont station. I think the asbestos will protect that somewhat. That calls to mind a very ingenious switch I saw in Montreal last winter, under which they used compressed air, and to my mind I think it is the coming switch. It not only breaks the arc suddenly, but cools off the contact part, thereby lessening the volatization of the metal which is feeding the arc, and I think it is going to be an element in the coming successful switch.

MR. MARTIN. Assuming you have two parallel lines in the generating substation, you have parallel busbars; you are operating, and desire to cut out one of the circuits and still maintain continuous service. I see no reason why the load cannot be transferred from one high potential to the other so that the entire circuit is practically feeding from the new circuit which you have just thrown in, and then relieving your high tension switches, which are connected to the busbars at generating substations, and in throwing those switches the load is being carried on the other circuit, and in a case of that kind you have no difficulty in throwing any kind of a switch.

Operation

STANLEY HIGH-VOLTAGE TESTING SETS.

THE continued raising of the voltages in commercial use in electric power transmission practice, together with the absolute necessity for reliable means for the delivery of extreme pressures in factory and station tests of insulators, insulating materials, machinery, etc., have caused the Stanley Electric Manufacturing Co. to bring out the high-voltage testing set about to be described. Many and varied forms of testing sets for such purposes have been brought out, but the Stanley set is the more familiar one in and about central California for the reason that it has been adopted and is in use by both the Standard Electric Co. and the Bay Counties Power Co.

These sets may be connected up in either one or two ways, which are known as "Plan A" and "Plan B," respectively.

"Plan A" includes, besides the testing outfit proper and a switchboard, a transformer wound to change the supply-line pres-

sure to test-line pressure, which is generally 50 or 100 volts. A rheostat is introduced between this transformer and the test line to accomplish any desired further regulation. Leads are taken from the test line to each of the "30 G^2 O" transformers, as shown in Figure 1. These three transformers are introduced into the circuit purely as a precautionary insulation. The secondaries of each of these transformers are connected in multiple to three individual sets of Stanley "type 3-C" special oil transformers, changing the test-line pressure from 50 or 100 volts to 10,000 volts Connecting the secondaries of these twelve transformers in series affords at the end terminals a maximum pressure of 120,000 volts.

The advantages of this arrangement are many. The introduction of the "30 G^2 O" transformers, as a precautionary insulation precludes the possibility of any accident producing a strain upon the system of the extreme high potentials dealt with. The carrying of the 10,000-volt terminals each to a solid stationary contact post mounted on the terminal board, as shown in Figure 2, prevents the possibility of their coming into undesirable proximity.

Between points having a difference of potential exceeding 40,000 volts there intervenes the insulation of four transformers.

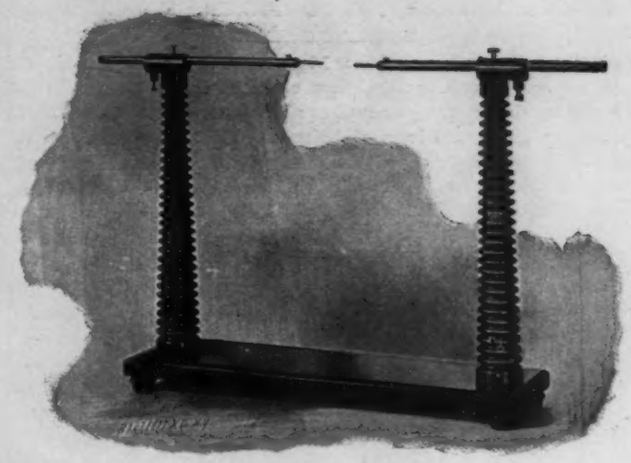


FIGURE 2—SPARK GAP.

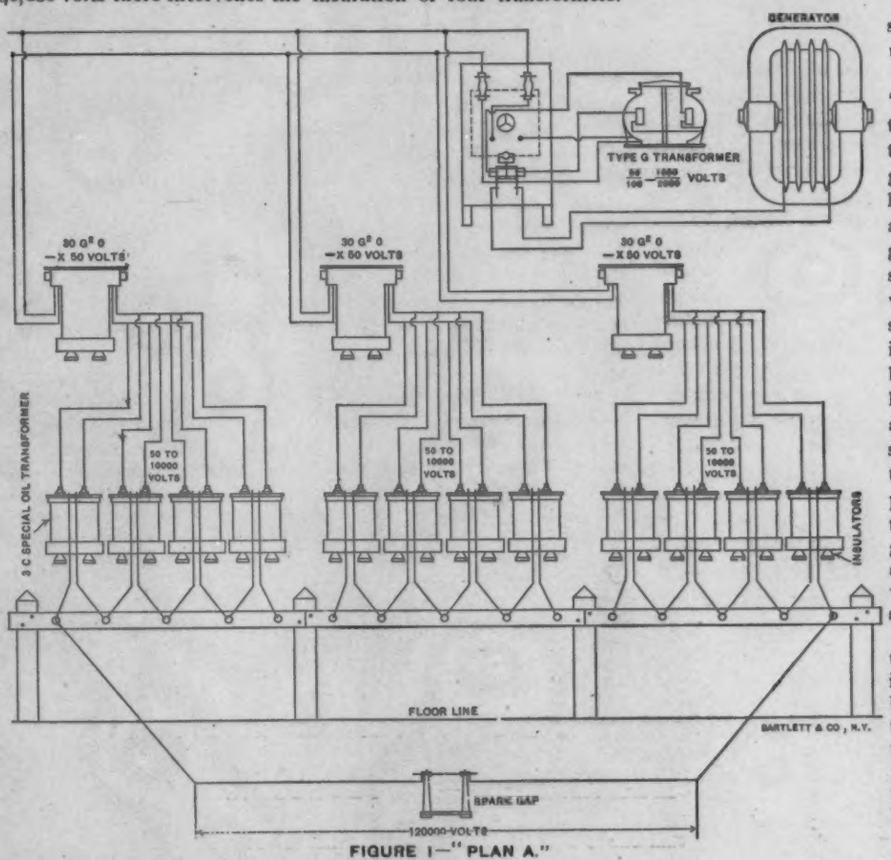


FIGURE 1—"PLAN A."

The path for any such short circuit must therefore overcome this insulation, which in each transformer is designed to provide for just such emergencies. Each one is subjected to thorough and severe tests before leaving the factory. The "3-C" and the "30 G^2 O" transformers are special transformers, most highly insulated and designed particularly for this special use and arrangement.

The test leads are flexible and may be attached to any of these contact posts, thus providing an adjustment of steps of 10,000 volts from 10,000 to 120,000 volts, intermediate variations to be effected by the rheostat. These flexible terminals should be of standard manufacture highly insulated. It is not contemplated that they will be handled while alive. Before making adjustments, the main switch should be opened. The "30 G^2O" and the "3-C" transformers must be thoroughly insulated from the ground by means of wooden blocks, and glass or porcelain insulators. Should one of the "3-C" transformers from any mishap fail, it is but a simple matter to bridge the secondary terminals and disconnect the primary terminals of same and operate at the reduced voltage until repairs can be effected.

"Plan B" is substantially the same as "Plan A," except the testing line is taken direct from the generator through type C fuses, and will suffice when the generator is accessible for desired regulation. The spark-gap is used virtually as a voltmeter, and the curve in Figure 3 gives the voltages at which the sparking should take place from 5000 to 150,000 volts. This spark-gap is designed to withstand the tremendous voltages to which it will, in practice, be subjected. The base is 18 inches by 5 inches of best quality hard rubber, ¾ of an inch thick, the edges are beveled and the whole is neatly and substantially put together. Extra insulation is provided by the four legs or supports. The posts carrying the adjustable terminals are of a form offering the greatest creepage resistance. They are also of best quality hard rubber and the whole will successfully withstand a pressure many times that for which designed.

The only other feasible apparatus for the production of high-testing voltages is the single transformer. These have been built to supply such pressures, but they are expensive, unwieldy affairs, and to be avoided if possible. There is no comparison between the single great transformer and the combination of units herein described, which affords a flexible and portable outfit possessing all the qualities to be desired.

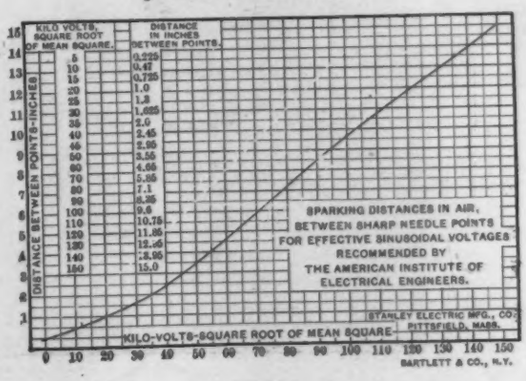

KILO VOLTS, SQUARE ROOT OF MEAN SQUARE.
DISTANCE IN INCHES BETWEEN POINTS.
DISTANCE BETWEEN POINTS-INCHES
SPARKING DISTANCES IN AIR, BETWEEN SHARP NEEDLE POINTS FOR EFFECTIVE SINUSOIDAL VOLTAGES RECOMMENDED BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
STANLEY ELECTRIC MFG. CO. PITTSFIELD, MASS.
KILO-VOLTS-SQUARE ROOT OF MEAN SQUARE
BARTLETT & CO., N.Y.

FIGURE 3.

THE ISKER-SOPHIA POWER TRANSMISSION.

BY FRANK C. PERKINS.

IN the valley below the Vitos Mountains, in Bulgaria, is located a power plant for supplying elecrical energy to the city of Sofia, for lighting and power purposes. The transmission line is 20 kilometers long, and a part of the high tension circuit and pole line is seen in the accompanying illustration, Figure 1, as well as the turbine and generator house, the pipe line and the reservoir at the penstock on the mountain side.

The water for driving the turbines is obtained from the River Isker, the normal discharge of which is 5.6 cubic meters per second. The reservoir shown in the illustration has a capacity of 150,000 cubic meters, and is supplied through a tunnel into the mountains, reaching the mines in a length of about 1100 meters. The height of the tunnel is 2.5 meters, the breath is two meters, and the grade is two per cent. The length of the steel pipe from the reservoir to the turbine house is 110 meters and the hydraulic head is 52 meters. The pipe is in sections 6 meters long, and it has a thickness of 5.8 millimeters, the diameter being 1400 millimeters.

The interior of the turbine and generator room is illustrated in Figure 2, showing four generators directly connected to four turbines, while sufficient space is reserved for adding two more units when necessary. The water wheels are of the high pressure turbine type built by Piccard, Pictet & Cie, of Geneva, and each has a capacity of 500-horsepower at 400 revolutions per minute. This gives the power house a total present capacity of 2000 horsepower, with a possible increase to 3000 horsepower. The turbines may be regulated either by hand or automatically as desired, the hydraulic regulators seen in the illustration being operated by power from the turbine shafts with belt transmission. The turbines and alternators are directly connected by flexible insulating couplings and the generators are insulated from the earth. The alternators were supplied by the Maschinenfabrik Oerlikon, of Oerlikon, Switzerland, and are of the polyphase revolving field type. The revolving fields have 16 poles and, at 400 revolutions per minute, the three-phase current has a frequency of 52 periods per second. With 80 per cent. power factor, each machine has a capacity of 425 horsepower. The air space clearance is 5 millimeters. The exciters are six-pole direct-current machines, mounted on the ends of the alternator shafts, outside the main bearings. The switchboard is seen in Figure 2, at the right, in the turbine and generator room. The operating levers for the high-tension main switches are in this gallery, while the switches themselves are located in a room under the gallery, together with the various instrument transformers and regulators. On the switchboard are mounted the ammeters and voltmeters for both the exciters and

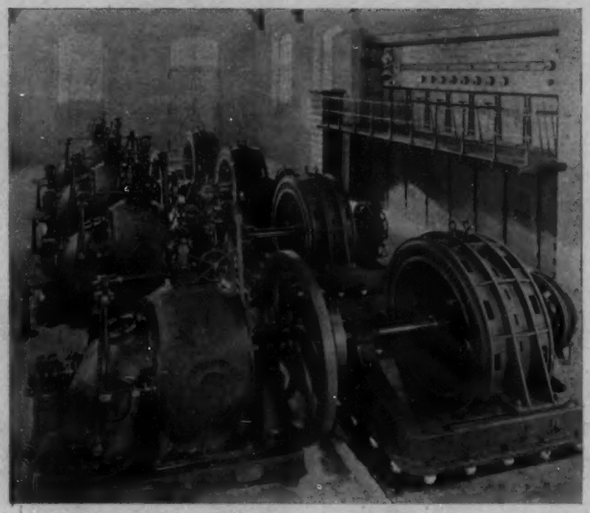


FIGURE 2---SOPHIA TURBINE AND GENERATOR ROOM, SHOWING THE SWITCHBOARD GALLERY.

alternators, as well as the controllers for the rheostats of the alternator fields and exciter fields. The switches and connections are so made at this board that the machines may be operated in parallel for supplying either or both power transmission lines, or any machine or set of machines may supply either line as desired. Each of the two high-tension power transmission lines consists of three copper conductors of 8 millimeters diameter. The total length of the transmission line to Sofia is 16.2 kilometers. At the outskirts of the city twelve substations are provided for supplying the lighting circuits at the outer edge of the city. In these the potential is reduced from 7200 volts to 165 volts for use, the distribution for these outlying districts being on overhead pole lines.

The secondary low tension distribution circuits are all carried through underground conduits in the central portions of the city, the potential being the same as that at the outskirts, namely, 165 volts. There are five underground sub-stations in the city proper, each of which reduces the potential from 3500 volts to 165 volts, and these sub-stations are supplied from a main transformer station which reduces the high potential of 7200 volts used on the transmission line to 3500 volts for distribution to the various sub-stations in the central part of the city.

The street railways of the city are also operated by electrical energy from the same source, a separate sub-station being provided for transforming the high-potential three-phase current to a working potential suitable for the railway circuits.

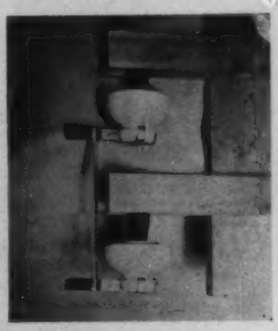
FIGURE 1---SOPHIA POWER HOUSE TRANSMISSION LINE AND RESERVOIR.

TWO SUCCESSFUL POLE LINE CUT-OUTS.

PIONEERING work in electrical development is generally characterized by modest efforts, and it has been frequently and truly said that ofttimes the pioneer builded better than he knew. High tension switching is an instance that is confirmatory of this, especially if pole line switches be considered. Briefly the facts are these: In September, 1895, the necessity for cutting out a branch line without interfering with the service of the main line, gave rise to the use of the pole line switch to be first described. In 1899 a similar condition of affairs arose on another Californian transmission, whereupon the switch of 1895 was altogether independently re-invented and improved upon as was necessary to handle an electromotive force nearly seven times that used in the first instance, with the result that the reports at hand declare it to be the most perfect high tension pole line switch in existence.

THE STARK CUT-OUT, OPEN.

The two switches referred to are those of E. E. Stark and O. H. Ensign respectively. When Mr. Stark, the well-known electrical engineer for John Martin, Pacific Coast agent for the Stanley Electric Manufacturing Company, was erecting the electrical equipment of the original power house of the Nevada County Electric Power Company, in the Fall of 1895 some difficulty was encountered in the application of electric power to mining work because of the use of current at 133 cycles, and in order to avoid disturbing the main line Mr. Stark devised and put into service the device which is believed to have been the first high tension switch and fuse ever used in California. The Nevada county circuits were operated at 5000 volts, supported on Locke insulators of the porcelain type then in vogue. The pole on which the cut-out was mounted was double-armed and on the tops of the two insulators placed thereon was secured clamps, one of which was electrically connected with the main line, while the other went to the branch line. Each of these clamps supported a clip of spring brass, into which fitted an insulating tube containing a fuse wire and having a brass cap on each end. These insulating tubes were of bamboo in the original equipment, although they are now made of glass. The brass caps of the tubing fitted into the clips, thus completing the circuit. Two or four such clip-sets are used on a pole, according to whether a single phase, or a two-phase, four-wire service is to be controlled.



THE STARK CUT-OUT, CLOSED.

The marked originality of the Stark pole cut-out rested in its application to pole line service, and to the fact that it could be operated from the ground. The latter was done by means of a 20-foot wooden pole, having at its upper end a push or pull clip that was controlled by a spring latch operated by a cord from the ground below. The device proved to be remarkably successful, and is today being used, and still installed, in all the 5000-volt power work of the Bay Counties Power Company in Nevada county. Two varieties of the switch are in use, namely, the vertical and the horizontal types, the former of which is illustrated herewith in its open and closed positions. Of the two types, the vertical form is liable to hold the arc when under heavy load, but the horizontal type is perfectly reliable.

A worthy improvement upon the Stark switch is in use on the 33,000-volt lines of the Edison Electric Company of Los Angeles. It is also mounted on the tops of insulators, and, in fact, differs from the Stark pole line cut-out mainly in its dimensions and in the use of horns, which pull out the length of the arc as it rises until finally the breaking point is reached. The principal of the arc breaking device is identical with that of the magnetic blow-out of the old form of lightning arrester, which was first used on Thomson-Houston arc circuits, but in the Ensign cut-out, the arc rises from its own heat, instead of being blown out magnetically. The device is operated from the ground by a pole and the circuit is opened by pulling out a fuse-holding insulated tube, as is done in the Stark cut out.

It is in regard to the operation of this switch that Mr. Ensign has stated, in a letter to the writer, that:

"We have something which absolutely works, as it is utterly impossible for an arc to hang, and yet the points of contact on our switch are 8 or 9 inches apart and fixed. We successfully break loads of 3000 or 4000 up at 33,000 volts, or with the whole kinetic energy of our system thrown into a short circuit, blowing a fuse, the cut-out will not make an arc 2 feet long and will go out instantly. Until we brought out this device we found nothing that we could absolutely rely upon."

Distribution

ROTARIES VS. MOTOR-GENERATORS.

AN interesting comparison of the relative efficiencies and cost of static transformers and rotary converters as against motor-generators receiving the 11,000-volt current direct into the motor, and converting it into 600-volt direct current by means of a generator coupled to the same shaft, is given in the following table, which is due to H. G. Stott, electrical engineer of the Buffalo General Electric Company.*

EFFICIENCIES: 200-KILOWATT UNITS.

	Transformer.	Rotary.	Combined.	Motor.	Generator.	Combined.
Full load.....	97.5	93.0	90 67	95	92	87.4
¾ load.....	97.1	92.5	89.81	94	91	85.54
½ load.....	96.0	90.0	86.40	92	88.5	81.42

From the above table it will be seen that the transformer and rotary converter give 3.27 per cent. at full load, 4.27 per cent. at three-quarter load, and 4.98 per cent. at one-half load better efficiency than the motor-generator set.

The investment shows a saving in favor of transformers and rotary converters of about 19 per cent., so that for purposes such as railroad work, where no great refinement of regulation is required, the rotary is beyond doubt the best and most economical.

Industrial

In responding to advertisements in this publication kindly mention "The Journal of Electricity, Power and Gas."

A NEW POLE AND CROSS ARM FIRM.

Messrs. George E. Carter & Co. have opened offices in room 28, third floor of the Crocker building, San Francisco, and announce that they are making a specialty of handling square sawn redwood or round red cedar poles, and pine cross arms, for transmission poleline purposes. The firm is prepared to make quotations on sizes and quantities to suit demands, with deliveries to all points reached by rail or water.

*From a paper on "The Distribution and Conversion of Received Currents," read before the American Institute of Electrical Engineers, N. Y., March, 1901.

Literature.

A NEW BOOK.

"THEORY AND CALCULATION OF ALTERNATING CURRENT PHENOMENA," by Charles Proteus Steinmetz, with the assistance of Ernest J. Berg. Third edition, revised and enlarged. New York: *Electrical World and Engineer*. 525 pages, 210 illustrations. Price, $4.00.

The third edition of the work before us contains such a wealth of information that the reviewer is embarrassed in making a choice of parts for particular comment. A work of Mr. Steinmetz requires no praise, for what but meritorious could come from so gifted and talented a man? It need hardly be said that the book is not for the tyro who intends to tackle alternating currents and learn all about them in the span of a few weeks or months. The book itself is a good illustration of the largeness of the realm of alternating currents. It is no introduction to alternating currents, but it is a wonderful book for the profound and earnest student, taxing his mathematical and reasoning powers to the utmost, and, in general, rewarding him for his pains. There is, right at the outset, a chapter perhaps the most charming and original of the whole work. We allude to the sixth chapter, entitled "Topographic Method." The diagrams for a transmission line with distributed capacity, inductance, resistance and leakage are conspicuous by solving with the greatest ease in the most elegant manner a problem at first sight appearing most abstruse and complex. These diagrams go to show that their author is as familiar with graphic methods as he is with the algebra of complex imaginary numbers. Another most admirable chapter is the eleventh, on "Foucault or Eddy Currents." Clear, simple and concise, it is a perfect example of how mathematics should be applied to the solution of physical or engineering problems. No waste of thought occurs in this chapter—the results are reached by the shorter road. A paragraph is devoted to the unequal current distribution in conductors through eddy currents, or the phenomena usually termed "skin effect."

Chapter XIII deals from the mathematical point of view with the problem of distributed capacity already treated in the sixth chapter by the topographic method, as throughout the volume, the authors treat and solve this problem with the help of complex imaginary numbers.
agiuary numbers.

Chapters XIV, XV and XVI treat of the theory of the alternating current transformer and of the induction motor, with an elaborate and most instructive theory of the concatenation of these motors. The authors start by developing the vestor-diagram of the transformer and then go on to express all quantities in the symbolic method, a procedure highly to be recommended. The name "frequency converter" is made use of for the general alternating current transformer with revolving secondary or primary, as illustrated by the induction motor. Though the treatment is almost everywhere clear and comprehensible, and though diagrammatic representation is often made use of for elucidation, yet it cannot be denied that the formulas are rather appalling, though this is more in seeming than in reality. Might not a graphic treatment of the involved phenomena in transformers and motors after all prove more perspicuous and lucid? It would hardly be considered justifiable, as it was once done, to express the motion of a slide-valve in mathematical raiment, owing to the fact that the slide-valve diagram is simpler and fully answers the purpose. It is not the complexity of the solution, it is the fact that there is a simpler solution possible, that makes us, to say the least, regret the absence of a detailed graphic treatment of the questions involved. Steinmetz's great work suggests another important question, viz., whether we are justified in giving in a book, written obviously for engineers and not for mathematicians, purely theoretical and mathematical deductions without giving experimental illustrations, as long as there are methods available which, without abating an iota of accuracy, would lay the results before the student in a more tangible and palpable form? Most interesting and suggestive is also the chapter on the synchronous motor. Graphic methods are constantly made use of in this chapter, but we must own that Prof. Blondel's development of the V-curves represented in Figs. 154 and 155, is briefer and more elegant. In this place we cannot forbear from remarking that it is surprising that in a scientific work of this knd no references are made to the works of other workers in the same field. There is hardly a problem in the wide field of alternating currents on which the best theorists have not tried their strength. Far from disputing the originality of the work of a man of such natural mathematical genius as Steinmetz, it has to be borne in mind that most of the problems in alternating currents with which this book deals were not first solved by the author, though the author is doubtless in America the foremost representative of the laborers in alternating current theory. The most prominent features of the book are so well known as to require little comment. A new, but rather brief, chapter on the transformation of polyphase systems has been added and the two appendices on the "Algebra of Complex Imaginary Quantities" and on "Oscillating Currents" conclude the book, as in the first and second editions.

The use of complex imaginary quantities cannot highly enough be recommended. The student of mathematical physics knows that since the time of Sir William Rowan Hamilton's great work on quaternions, vector-algebra has developed into a most powerful calculus. All men of great mathematical genius seem to have recognized the power of the symbolic method. What admirable use was made of this method, students may see from the works of that most powerful mathematician, William Kingdon Clifford, whose name we may not write without the expression of deepest regret that such a noble mind was lost to the world in the early prime of its powers without being able to finish a great work. We cannot think of a more useful introduction to Steinmetz's book than Clifford's "Common Sense in the Exact Sciences," edited by Prof. Karl Pearson, and Clifford's "Dynamic," edited by Prof. Tucker. Euler's formulas and De Moivre's theorem, so puzzling to the beginner, are here shown to be merely symbolic expressions of common sense facts, and diagrams are used to illustrate graphically the meaning of the complex imaginary number. Considering that this work of Clifford's was done almost a quarter of a century ago, it appears most wonderful how few of the crumbs from the table of this rich genius have been appropriated by the scientific world at large. The human mind is apt to unconsciously ignore the work of its predecessors and to consider everything as new when it is first thrust upon its perception.

We said at the outset that the author's work requires no word of praise, and we only wish to say in conclusion that the work before us is one deserving of most careful study, a mine of valuable information, one of those mines, it may be said, that will yield treasures to all who dig in them.

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